IMPERIAL INSTITUTE

MONOGRAPHS ON MINERAL RESOURCES
WITH SPECIAL REFERENCE TO THE
BRITISH EMPIRE

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MONOGRAPHS ON MINERAL RESOURCES WITH SPECIAL REFERENCE TO THE BRITISH EMPIRE

PREPARED UNDER THE DIRECTION OF THE MINERAL RESOURCES COMMITTEE OF THE IMPERIAL INSTITUTE WITH THE ASSISTANCE OF THE SCIENTIFIC AND TECHNICAL STAFF

PETROLEUM

PREPARED JOINTLY WITH

H.M. PETROLEUM DEPARTMENT

WITH THE CO-OPERATION OF

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WITH A MAP AND 3 DIAGRAMS

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IMPERIAL INSTITUTE

MINERAL SECTION

THE Imperial Institute is a centre for the exhibition and investigation of minerals with a view to their commercial development and for the supply of information respecting the sources, composition and value of minerals of all kinds.

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A special staff is engaged in the collection, critical revision and arrangement of all important information respecting supplies of minerals especially within the Empire, new methods of usage and other commercial developments.

Articles on these and related subjects are periodically published in the *Bulletin of the Imperial Institute*, and monographs on special subjects are separately published under the direction of the Committee on Mineral Resources.

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PREFACE

THE Mineral Resources Committee of the Imperial Institute has arranged for the issue of this series of Monographs on Mineral Resources in amplification and extension of those which have appeared in the *Bulletin of the Imperial Institute* during the past fifteen years.

The Monographs are prepared either by members of the Scientific and Technical Staff of the Imperial Institute, or by external contributors, to whom have been available the statistical and other special information relating to mineral resources collected and arranged at the Imperial Institute.

The object of these Monographs is to give a general account of the occurrences and commercial utilisation of the more important minerals, particularly in the British Empire. No attempt has been made to give details of mining or metallurgical processes.

HARCOURT,
Chairman Mineral Resources Committee.

IMPERIAL INSTITUTE, LONDON, S.W.7.
July 1920.

CONTENTS

CHAPTER I

CHAPTER II

CHAPTER III

PETROLEUM

CHAPTER I

PETROLEUM: ITS CHARACTERISTICS; OCCURRENCES; MINING; REFINING AND USES. DIAGRAMS OF PRODUCTION

INTRODUCTION

ONE of the features of the recent war was an extraordinary development of the uses of petroleum in munition factories, motor transport services, aviation, tanks, and warships of all classes; every phase, in fact, of both naval and military operations led to demands for petroleum products in ever-increasing quantities. With the renewal of peace activities, these requirements seem likely to be maintained, and possibly augmented, since the adoption of fuel oil on a large scale by the mercantile marine may well be regarded as certain.

As petroleum has thus become a vital necessity in the life of every nation, it has been thought desirable to issue a short summary of the petroleum resources of the Empire and of the world so far as they are at present known. The information has been largely taken from the most recent official reports, though acknowledgment must also be made of the assistance in many points of detail that has been obtained from current standard works on the subject. The disturbed conditions which at present prevail in some countries have made it difficult, if not impossible, to secure the latest and most accurate particulars, but it is hoped that this brief summary may prove a useful source of reference, and enable a compre-

hensive view to be obtained of the resources available to meet the constantly increasing demand.

Within the last twelve years the output of petroleum has been more than doubled, increasing from about 35,000,000 tons in 1907 to about 80,000,000 tons in 1919. The following table shows in metric tons the output of the principal oil-producing countries in the world for the period 1916–1920:

—	1916.	1917.	1918	1919.	1920.
U.S.A.	42,966,737	47,902,228	49,357,143	53,959,857	63,343,143
Russia	10,400,160	8 362,903	3,143,960	3,642,571	3,483,143
Mexico	5,792,245	7,898,967	9,118 332	12,430,000	22,800,000
Dutch E. Indies	1,730,180	1,687,391	1,700,675	2,092,917	2,250,000
Roumania	1,244,093	517,491	1,214,219	905,064	1,017,382
Persia	587,502	937,902	1,131,489	1,194,000	1,712,267
British India	1,188,759	1,131,038	1,146,340	1,222,607	1,000,000
Galicia	927,440	901,910	678 640	818,333	752,528
Other countries	1,743,138	1,812,804	1,904,175	1,814,406	1,153,063
Total	66,580,254	71,152,724	69,490,973	78,088,755	97,511,526

It will be observed that the United States has been by far the largest contributoı, her share of the world's production increasing from 64% in 1916 to nearly 68% in 1919.

Characteristics of Petroleum

Crude petroleum, or "rock oil," as it occurs in nature, consists of a mixture of complex hydrocarbons, chiefly of the paraffin, benzine and naphthene series. The proportion of the several components varies according to the locality from which the oil is derived, and often, oils from different wells in the same field show variation in composition.

For practical purposes, crude oils may be considered as belonging to either one of two types: asphaltic oils, which yield on slow distillation a dark asphaltic residue, and paraffin base oils, which yield, on cooling to a low temperature, light-coloured solid hydrocarbons, chiefly of the paraffin series. It must, however, be understood that the two types merge into one another.

On subjecting a crude oil to fractional distillation, a series of distillates of different boiling points and specific gravities may be obtained. This operation, carried out on a commercial scale in refineries, is made to yield such fractions as will best fulfil the requirements of trade. Thus a volatile oil, variously described as naphtha, benzine, petrol, gasoline, motor spirit, etc., is the first product of distillation; this is followed by illuminating or lamp oils, solar oils and lubricating oils—as the temperature becomes progressively higher.

The colour of crude petroleum, when viewed by transmitted light, varies considerably from yellow, green and red, to reddish brown, and through various shades of brown to black. In reflected light it usually exhibits a greenish cast, which enables it to be distinguished from refined oils, which show a bluish fluorescence.

Oils from certain regions possess characteristic odours. In this way one may recognize petroleums from Pennsylvania, California, Texas, Russia and the East Indies, whilst petroleums from Mexico, Ontario, Ohio and Indiana, which contain sulphur compounds, possess odours which are decidedly disagreeable.

Crude petroleums usually range in specific gravity from 0·820 to 0·940, although lighter and heavier varieties are sometimes found. In fact, they may be said to vary through every intermediate gradation, from thick and black liquids with a density greater than water, to light-coloured and highly mobile fluids with a density as low as 0·77.

The Occurrence of Petroleum

Crude petroleum is widely distributed in the world, being found in many countries, sometimes only in insignificant amounts, but not infrequently in such quantities as to furnish supplies of great economic importance.

In its natural state petroleum occurs in bedded or stratified sedimentary rocks, and more particularly in those which are of a porous nature.

The geological distribution of oil in the chief oil-fields is shown in the following table:

Geological formation.	Percentage of total production	Localities.
Tertiary	49·4	California, Gulf Coast, Russia, Roumania, Persia, Dutch E. Indies, Peru, Argentine, Venezuela and most British Colonies.
Upper Cretaceous	1·0	Texas, Wyoming, Colorado and Galicia.
Lower Cretaceous		
Jurassic		
Triassic		
Permian		
Upper Carboniferous		Texas, Oklahoma, Kansas, Pennsylvania.
Lower Carboniferous	41·5	Illinois, part of Appalachian field (U.S.A).
Upper Devonian		Part of Appalachian field (U.S.A.).
Devonian		Canada.
Silurian		
Ordovician	8·1	Lima-Indiana (U.S.A.).
Cambrian		

It will be seen that the greatest amounts of petroleum come from the Tertiary, Carboniferous, and Devonian formations, which, as far as geological survey has shown, cover 60% of the earth's surface.

It appears probable that in most cases the oil has migrated from certain beds, in which it was generated, to others, known as the storage-rocks, which it now occupies, although opinions differ as to the extent of such migration. With regard to the formation of petroleum in nature, little is known, but it is generally agreed that it is in some way connected with complex changes undergone by organic remains, whose exact nature is a subject of dispute, but which were accumulated with the inorganic portion of the sediments making up the bulk of the "generator-rock." Obviously the fatty portion of the organic remains has, by a series of chemical changes under special conditions, whose nature is also disputed, given rise to the liquid hydrocarbons as we find them at the present day.

Three prime causes—gas-pressure, capillary action and gravitation—have affected the transference or migration of the oil from the generator-rock to the reservoir-rock, and likewise from one part to another of the latter. Gas, water (usually saline) and oil may be present, either separately

or together, in the reservoir-rock. Gas-pressure acts equally in all directions, and will force the oil out of the reservoir-rock, where there is a means of escape. Capillary action can produce movement of oil only in dry rocks, and especially in those possessing a close texture. As it is found that the amount of water present in rocks decreases with increase of depth, capillary action may have been an important factor in governing the migration of oil at considerable depths and during the early stages of the history of these movements. As regards the influence of gravitation, in dry rocks oil seeks the lowest part of the bed or beds of the requisite porosity, whilst in wet rocks it tends towards the highest point.

To prevent the escape of oil from the large accumulations or pools, there must be an overlying series of impervious beds, usually clay or clayey shales, and, moreover, the porous beds themselves must not crop out at, or communicate by means of fissures with, the surface. Sometimes oil-sands are sealed at the outcrop by bitumen, in which case most of the gas will have escaped. The third condition favourable to the accumulation of oil is that of a suitable geological structure. The sedimentary rocks are seldom quite horizontal; they are frequently inclined and often flexured or bent. Such flexures may take the form of anticlines, synclines, domes, or terraces. In folds of the anticlinal type the oil rises towards the apex, whilst, unless the strata are dry, it is absent from the synclines. A fourth factor which occasionally exercises an influence on the distribution of oil, though difficult of determination, is the change of porosity which a bed may undergo from point to point, due to a lack of uniformity in the character of the sediments themselves.

Besides the important anticlinal structure there may be other special structures which have exercised considerable influence on the localization of oil pools. Hence the selection of oil-bearing areas and the actual location of drilling sites must be based on the knowledge obtained in the course of a more or less extensive investigation by professional geologists.

In the United States, work of this kind has been carried to a considerable degree of perfection. Contoured maps of underground strata have been prepared from the results of

boring operations, whereby many local oil pools have been located amidst strata which are usually barren.

Certain surface " indications," such as oil-seepages, emanations of natural gas, mud-volcanoes, outcrops of oily or bituminous rocks and asphaltic deposits, are frequently of use to the prospector in his search for oil-bearing areas, but some oil-fields are devoid of such indications, and, even when they do occur, it does not necessarily follow that petroleum will be met with in commercial quantities. This point is liable to be overlooked by persons who are anxious to promote the development of suggested new oil-fields.

Petroleum Mining

The oil contained within the petroliferous beds is tapped by sinking bore-holes. This is carried out either by the percussion or by the rotary system. Describing the percussion system in very general terms, it may be said to consist of alternately raising and lowering a chisel-shaped heavy steel " bit," suspended from one end of a "walking-beam" by means of a cable or a long chain of poles. The rocking motion of the walking-beam is effected by a " band-wheel " driven by a steam engine. The detritus and water are removed by a " sand-pump " and bailer. When a depth has been reached at which the sides of the hole begin to cave in, or water is met with, it is necessary to line the hole with steel casing. A smaller bit is then used for deepening the well, which is carried forward until further caving or influx of water necessitates lowering another " string " of casing, which must be of such a diameter as to pass through the casing previously inserted. This procedure is repeated as often as necessary, the hole thus gradually decreasing in diameter as depth is gained.

In the rotary system a length of hollow drilling rods, to the lower end of which is attached some form of drilling bit, is mechanically rotated. The detritus is removed by forcing a continuous stream of water through the rods.

The rotary system, by means of which drilling can be carried on much more rapidly and cheaply than with cable tools, i[s] not, however, well suited for testing unproved fields. Th[e] water or liquid mud which is used under high pressure fo[r]

flushing the hole, tends to drive back any oil met with in the oil-bearing formation, so that it is quite possible to pass through a payable oil sand without its presence being recognized by the drillers. For this reason the ordinary chilled shot or diamond rotary drill as used for coal mining is also unsuitable, notwithstanding the advantage of being able to obtain cores of the strata passed through.

It is, therefore, customary to drill the initial test-wells by means of cable tools, and after it has been ascertained at what depth the oil horizons occur, the rotary system may be employed with advantage for drilling additional wells, in order to obtain a commercial production of oil.

Plant can now be obtained which permits of changing from one system to the other, so that the bulk of the drilling can be accomplished by means of the rotary system, and the change to cable tools can be effected when a depth has been reached at which oil may be expected to occur.

If the wells do not flow of their own accord, they must be pumped. Where a number of wells has to be dealt with a special mechanical arrangement enables them all to be pumped from a single power-plant, which reduces the cost very considerably. In this way a large series, perhaps consisting of 200 wells, may be profitably worked, even though the yield from each be only a few barrels daily. Other methods of raising the oil are by means of either an air-lift or a bailer.

The crude oil from the well either flows naturally, or is pumped into a tank situated near at hand. From this tank the oil is conveyed to the refineries by tank cars, or through pipe-lines, or, in some cases, by tank vessels.

The Refining of Petroleum

Where crude petroleum is not directly employed for fuel, it undergoes a process of fractional distillation in a refinery, whereby various products, or distillates, are obtained which meet trade requirements by falling within certain ranges of boiling-point and specific gravity. There is considerable overlapping and confusion in the nomenclature of these various commercial products, caused partly by the fact that crude oils

from different regions yield different sets of products and in various proportions.

There has also been a gradual change in the required quality of the various fractions of petroleum, e.g. petrol, which had originally a specific gravity of 0·680 and a final boiling-point of about 125° C., may now have a specific gravity of 0·750 or even higher, and a final boiling-point of 225° C. Refining may be partial, the lighter fractions only being taken off and the whole of the residue used as fuel, or the process of distillation may be continued, and gas oil, lubricating oils and paraffin wax also be obtained. Owing to differences of refinery practice and the varying qualities of crude oils, it is impossible to draw up a list of products which is of general application, but the following will give some indication of the characteristics of the various products.

--	Boiling points (° C.).	Flash-point.	Specific gravity.
Petroleum spirit (gasoline, petrol, naphtha, etc.)	Up to 200°	Below 73° F	0·650 to 0·750
Burning oil (kerosene or "paraffin")	150° to 300°	73° F. to 110° F.	0·800 to 0·825
Solar or gas oil	250° to 340°	150° F	0·865
Lubricating oils	340° to 500°	300° F. to 500° F.	0·900 to 0·950
Fuel oil	Above 300°	150° F. to 200° F	0·900 to 0·960

Not only do the distillates vary to some extent in nature and yield with the character of the crude oil, but a certain variation can be induced by modifying the manner in which the distillation is carried out.

Although all methods of refining are based on the same fundamental principle, they actually differ in detail, according to the particular nature of the crude oil which has to be treated. Described in very general terms, the modern process is carried out as follows. The crude oil, sometimes previously warmed by waste heat, is introduced into steel cylindrical stills of various designs, which are externally heated by fuel oil sprayed into the fire-box by a jet burner. In many cases steam, superheated if necessary, is admitted by a perforated pipe extending along the base of the still.

As the temperature is progressively raised, the successive distillates are collected in separate storage tanks. It was the practice formerly to carry out the distillation until the residue consisted of oils heavier than solar oil, and then to transfer this residue to a separate and specially-designed still for extracting the various heavy oils. A more modern practice, however, is to effect a complete distillation in one set of stills, which are modified by having a tower-like superstructure through which the vapours pass and become more thoroughly fractionated. As a rule, the greatest possible yield of petroleum spirit and burning oil is desired, though different proportions of products can be obtained according to market demands. The primary distillates require to be re-distilled and purified by acid treatment and agitation before they are fit for sale.

One result of the demand for light products has been the introduction of special operations known as "cracking" processes, whereby the heavier types of distillates can be broken down into lighter products. There are three methods of cracking heavy oils, viz. the *Rittman process*, which consists essentially in heating the vapour under pressure; the *Burton process* of heating the oil and condensing under pressure; and that of *heating the oil under pressure*. Uncracked oils are of better quality and command a higher price than similar products made by the cracking process.

Another result of the demand for light products has been the recovery of "casing-head" spirit, obtained from the gas given off by most wells producing oil. This gas generally contains light hydrocarbons in suspension, and the two methods generally employed for removing these hydrocarbons consist of—

(*a*) Absorption of the spirit in oil with subsequent distillation;

(*b*) Compression and refrigeration of the casing-head gas.

The first method is generally employed on so-called dry gas, i.e. gas containing less than one gallon of spirit per 1,000 cubic feet of gas, and the refrigeration method is employed on wet gas containing 1 gallon or over of spirit per 1,000 cubic feet. The total quantity of casing-head spirit produced in the United States during 1918 was 282,535,550 American gallons, which was extracted from 449,108,661,000 cubic feet of gas.

The results obtained by distilling petroleum of the Pennsylvania type will serve as an illustration of the nature of the products obtainable from a crude oil. Dry or destructive distillation yields a series of gasoline oils, both normal and cracked; a normal and cracked series of illuminating oils; a series of fuel oils; a series of lubricating or paraffin oils; paraffin wax, and wax tailings. The products of steam distillation include normal gasoline, illuminating oils, fuel oils, spindle oils, steam cylinder stocks and vaseline.

The Uses of Petroleum Products

The common uses to which some of the more important products are put are given below·

Petroleum Spirit.—Very light fractions are used as local anæsthetics; as cleaning solutions; as solvents for caoutchouc; and for other industrial purposes; but the main use of the more volatile products of petroleum is as fuel for internal combustion engines, under the names of gasoline or naphtha (U.S.A.); petrol or benzine (U.K.).

Illuminating Oils (burning oil or kerosene).—The different burning oils are known by a great variety of names. Provided the flash-point is satisfactory, the best burning oil is that with the lowest viscosity, lowest iodine absorption, highest gravity, lowest sulphur content, and best colour, i e. as nearly water-white as possible.

Fuel Oils.—This term includes a very wide range of products, from high-grade oils capable of being used in engines of the Diesel type, to heavy residues which are burnt under boilers. The use of fuel oil is extending very rapidly, particularly for marine purposes, and large numbers of ships are being fitted to burn fuel oil both in internal combustion engines and in furnaces. Increased quantities are being used on railroads, in power stations and for smelting works. The characteristics which a fuel oil should possess are: a high calorific value; a fairly high flash-point; fluidity at moderately low temperatures; and freedom from solid matter which might cause trouble with the atomizers.

Calorific Values of some Typical Fuel Oils

Source.	Specific gravity at 15° C.	Calorific value Calories.	Calorific value B.T.U.
Russia	0·914	10,990	19,780
Texas	0·930	10,790	19,430
Burma	0·900	10,610	19,100
Borneo	0·915	10,780	19,400
Mexico	0·952	10,445	18,800
Roumania	0·950	10,695	19,250
California	0·948	10,400	18,700
Persia	0·893	10,833	19,500
Trinidad	0·942	10,500	18,900

Gas Oil.—An oil of a gravity (about 0·865) intermediate between kerosene and fuel oil It is of low viscosity, and owes its name to its use for enriching coal gas. It is also much in demand as a superior fuel for oil engines of the Diesel and other types.

Lubricants.—Many kinds of lubricating oils in general use are refined from crude petroleum, and range from light spindle oils to solid lubricating greases.

Wax.—Paraffin wax is obtained from crude oils having a paraffin, as distinct from an asphaltic, base. It is used for making wax candles, waterproofing cloth, preserving foodstuffs, insulating purposes, etc.

The diagrams on the following pages show the quantities of petroleum produced by different countries in recent years.

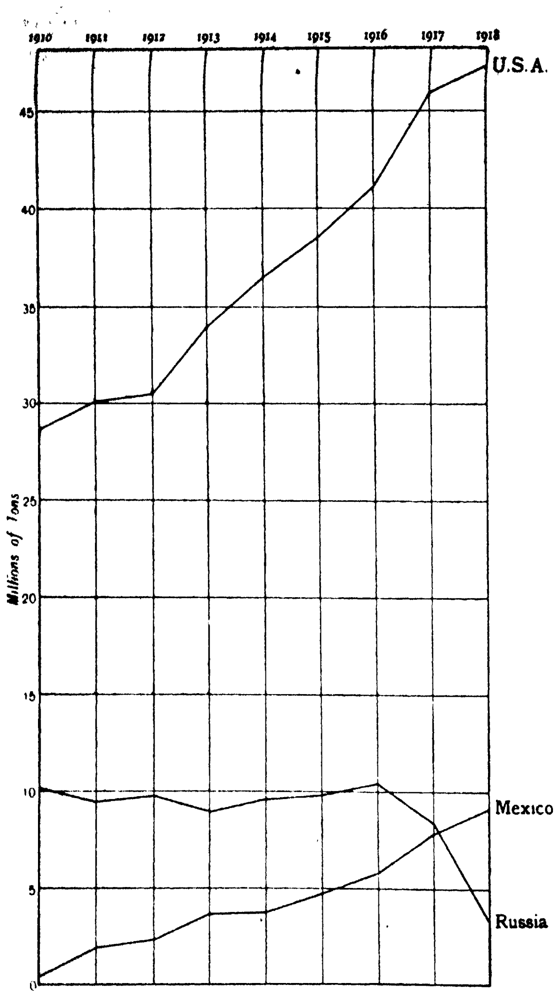


DIAGRAM I.—SHOWING PETROLEUM PRODUCTION OF THE THREE LARGEST PRODUCING COUNTRIES, 1910-1918.

(Millions of tons of 2,240 lb.)

Note.—For some additional information see table on p. 2.

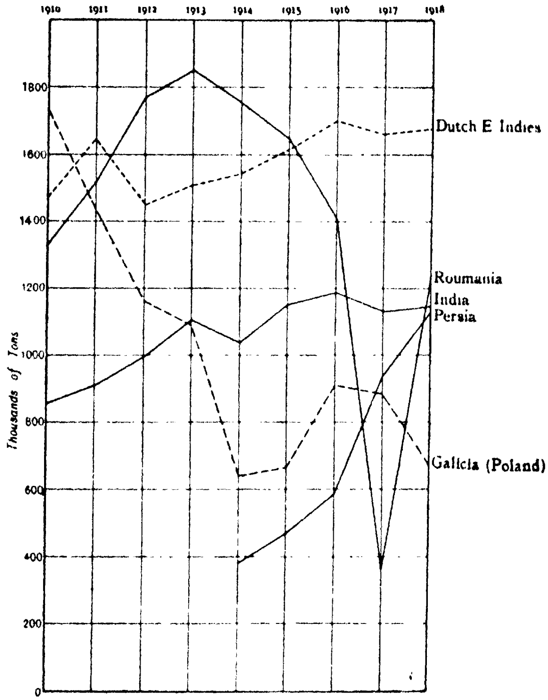


DIAGRAM II.—SHOWING PETROLEUM PRODUCTION OF FIVE MINOR PRODUCING COUNTRIES, 1910 1918.

(Thousands of tons of 2,240 lb.)

Note.—For some additional information see table on p. 2.

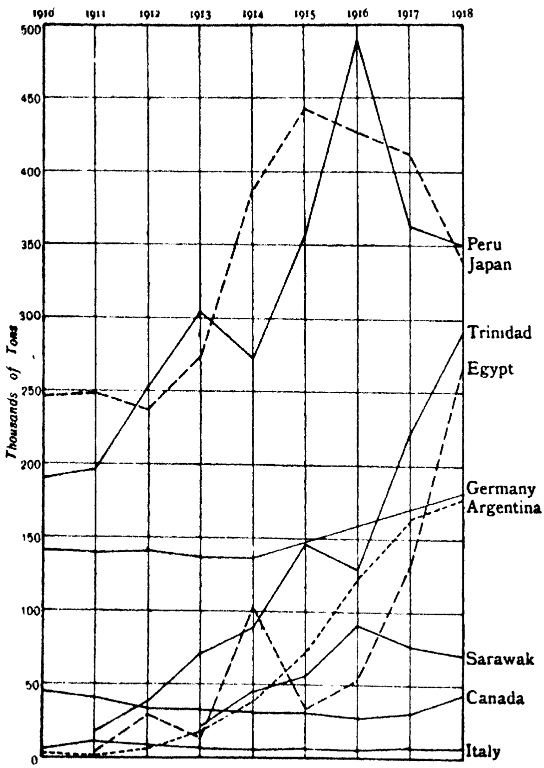


DIAGRAM III.—SHOWING PETROLEUM PRODUCTION OF NINE SMALLEST PRODUCING COUNTRIES, 1910-1918.

(Thousands of tons of 2,240 lb.)

CHAPTER II

SOURCES OF SUPPLY OF PETROLEUM

(a) BRITISH EMPIRE AND DEPENDENCIES

EUROPE

Great Britain

The United Kingdom is a comparatively small oil producer, practically all its requirements being drawn from overseas. Until quite recently production was confined to the shale deposits of Scotland, which are dealt with in the Oil Shales monograph of this series.

Occurrences of natural petroleum have, from time to time, been reported from various parts of the country, and in October, 1918, a systematic search for oil was begun by S. Pearson & Son, acting as agents of H.M. Government, a sum of £1,000,000 being set aside for this purpose. A series of bore-holes was put down in the Chesterfield area, and in May, 1919, a well at Hardstoft came in at a depth of 3,077 feet, with a daily flow of about 10 or 11 barrels of oil, and has since been steadily producing, under natural pressure, at the rate of about 7 barrels daily.

Tests have been also in progress in North Staffordshire (Apedale and Werrington), and in Scotland (West Calder and D'Arcy). At Kelham, near Newark, a well is being sunk by Oilfields of England, Ltd., and another near King's Lynn, by English Oilfields, Ltd.

A typical fractionation of the Hardstoft oil is as follows:

	Per cent.
Petrol	10·0
Kerosene	36·5
Gas oil	20·0
Lubricating oil	30·5
Paraffin wax	3·0

Specific gravity, 0·823.
Calorific value, 20,290 B.T.U.

A small show of oil was also met with in a boring for coal at Retford.

Some idea of the requirements, in tons, of the United Kingdom of petroleum products can be gauged from the following table:

Year.	Production.[1]	Imports.	Totals.	Exports.	Difference (Consumption).
1912 . .	294,699	1,653,333	1,948,032	26,846	1,921,186
1913 . .	289,684	1,962,427	2,252,111	16,505	2,235,606
1914 . .	285,464	2,586,850	2,872,314	20,444	2,851,870
1915 . .	263,083	2,354,079	2,617,162	46,079	2,571,083
1916 . .	247,472	3,159,195	3,406,667	27,907	3,378,760
1917 . .	249,598	4,187,569	4,437,167	20,800	4,416,367
1918 . .	242,501	5,297,984	5,540,485	7,074	5,533,411
1919 . .	213,886	2,855,535	3,069,421	112,977	2,956,444

[1] Crude oil distilled from oil shale.

The table on page 17 gives the imports of petroleum products from 1910 to 1919, showing countries of origin.

MALTA

It is possible that test drilling will be undertaken on the island as there are rocks of suitable age and structure.

ASIA

BRITISH BORNEO

Along the north-east coast of Borneo, from Sampanmangio Point to the Sadong district, indications of the presence of petroleum, in the Tertiary coal-bearing series, appear at numerous points in British North Borneo, Brunei and Sarawak, as well as on the adjacent islands of Labuan and Mangaloon.

In Brunei and British North Borneo, both English and Japanese companies are engaged in prospecting for oil.

Two wells have been sunk on Mangaloon Island, but neither has yet arrived at a depth at which oil could be expected. Of four wells sunk on the Klias Peninsula, two met with small shows of oil, and No. 4 produced a return of 1,200 gallons daily. These wells, however, are not being operated upon at present.

Imports into the United Kingdom of Crude Petroleum and Petroleum Products

(Quantities in thousands of Imp. gallons.)

From	1910	1911.	1912	1913	1914	1915	1916.	1917.	1918.	1919.
British possessions	461	11 275	18 152	22 183	32 380	32 974	61 656	94,259	162,611	60,696
Russia	28,417	43 586	31,738	38 201	21 172	—	—	—	—	739
Roumania	24 702	30 000	53 056	57 306	25 540	—	—	—	—	—
Dutch E. Indies	25 538	18 687	32,325	30 221	44 552	48 100	49 114	33 832	32 386	35,038
Persia	—	—	—	1 528	13 517	4 815	136 818	135,644	473	23,958
United States	251,701	240 044	260,131	303 031	451 071	420 634	495 626	729,284	1,023,283	468,641
Mexico	4 142	—	2,787	20,079	47 215	62 870	46 442	52,114	101,788	129,405
Peru	—	—	—	—	3 395	6 529	—	—	—	—
Other foreign countries	10,539	13,071	15 143	14,807	7 272	6 543	145	1,820	3.954	2,938
Totals	345,680	365 072	413.332	488,106	646 714	588 471	789,801	1,046,953	1,324.495	721,415

SARAWAK

The producing field is in the Miri district of Sarawak. A refinery has been erected at Lutong, as well as tank storage, and there are two 8-inch submarine pipe-lines for the shipment of products.

Production has been as follows:

	Tons.
1913	19,953
1914	45,039
1915	55,460
1916	90,570
1917	76,738
1918	71,366
1919	85,143
1920	148,033

The decrease in 1918 compared with 1917 was due to lack of shipping, which also involved the curtailment of plans for a more vigorous drilling programme.

The following is a typical distillation test of the Sarawak oil:

Specific gravity	0·924
Benzine	9%
Illuminating oil	26%
Gas Oil	7%
Residuals	58%

CYPRUS

Indications of petroleum in Cyprus seem to be confined to the dark oil-bearing phase of a crystalline limestone formation, probably of Cretaceous age, occurring in the northern mountain range, but the physical character of this rock and the structure are unfavourable to the accumulation of oil on a commercial scale.

INDIA

Oil has been found to a small extent in the Punjab and Baluchistan, but the main petroleum-producing region of India is in the east, i.e. in Burma and Assam.

By far the greatest supply of oil in India comes from Burma, which in 1915 furnished 98% of the total production, whilst 69% of this total yield was from the Yenangyaung oil-field.

Burma.—In Burma the chief oil-bearing area runs north and south, along the basins of the Irrawadi and Chindwin rivers. In the 400 miles along which indications exist, only isolated spots in a section of the belt about 90 miles long have been found sufficiently profitable for development up to date, the chief fields being Yenangyaung (Magwe district), Singu (Myingyan district), and Yenangyat (Pakokku district). The Yenangyaung field is the most important, its three sections being Twingon, Khodaung, and Beme. All these fields are connected by pipe-lines which continue to the refineries at Rangoon. Other areas in which petroleum occurs are Chindwin, Shwebo, Minbu, Thayetmyo, Prome, Henzada, and the Arakan region, comprising Ramri and other small islands. The work done in these districts has, however, been principally of an exploratory nature, though increasing amounts of oil are now being won from Chindwin and Minbu.

The oil occurs in anticlines and domes of the Pegu series (Miocene and Oligocene), often projecting as small hill ranges through plains consisting of Irrawadi sandstone (Pliocene) and recent surface deposits. In a few places the Nummulitic series (Eocene) are petroliferous.

The Yenangyaung field is situated on the left bank of the Irrawadi, about 270 miles north of Rangoon and 130 miles S.S.W. of Mandalay. A denuded dome forms at the surface an elongated ellipse of Pegu beds, surrounded by an outcrop of Irrawadi sandstone. The oil occurs in a complex series of lenses, streaks and beds of sand, varying considerably in thickness at different points and situated at various horizons in impervious clays. In 1914 productive sands were tapped at a depth of nearly 3,000 feet.

The oil has a specific gravity varying from 0·800 to 0·950.

The following gives a general indication of the composition of the crude oil:

	Per cent.
Naphtha	15
Kerosene	55-60
Solid paraffin	12-14
Lubricating oils	8-12
Loss and coke	5

The Singu field is 30 miles north of Yenangyaung, upon the same bank of the Irrawadi, and the main producing portion of the Yenangyat field lies 30 miles still farther north, upon the opposite bank of the river. Both fields are situated upon a single asymmetric anticlinal fold, which rises and pitches in three places, producing local dome-structures, each of which forms a separate oil-field. At Singu the oil-sands are fairly constant and occupy two main horizons, one at about 1,500 feet and the other at 1,850 feet, whilst at Yenangyat there is much inconstancy, which is also characteristic of the Yenangyaung field.

Full details of the petroliferous localities within the several districts of Burma may be obtained from the *Memoirs of the Geological Survey of India*, vol xl, on the "Oilfields of Burma."

Assam.—The oil-belt of Assam is crescent-shaped and some 800 miles in length from the extreme north-east of the province to the islands off the Arakan Coast of Burma. The only fields of commercial value, so far discovered, are those of Digboi, Bappa Pung, Makum, and Badarpur. The oil is confined to the Coal-Measure Series, which consists of alternating shales and sandstones with seams of coal, probably of Oligocene and Miocene ages. These Tertiary rocks are folded generally symmetrically. In places overfolds towards the N.W. occur.

The petroliferous portion of the Digboi field has an area of about 130 acres and is about 16 miles N.E. of Jaipur. The specific gravity of the oil is about 0·85. On distillation it yields the following percentages: benzine, 10; kerosene, 55; intermediate oils, 15; lubricating oils, 8; paraffin wax, 9; and coke, 3. The oil is sold locally, but much of the wax is sent to England, and is very suitable for the manufacture of candles for tropical climates. There is a fairly constant oil-horizon at from 1,100 to 1,200 feet, although the main supplies are usually obtained from a depth of from 1,400 to 1,700 feet. The structure of the field is probably that of an asymmetrical dome with a W.S.W. axis and an overfold towards the north.

The Bappa Pung field lies about a mile E.N.E. of Digboi,

and is connected with it by a light railway. Apparently the structure closely resembles that at Digboi.

The Makum oil-field is situated about 8 miles E.S.E. of Digboi.

The Badarpur oil-field is close to the town of the same name, on the borders of Sylhet and Cachar. Since 1915 it has been worked by the Burmah Oil Co. Recent data are not available, but it is known that at least 21 wells have been sunk, of which 19 were producing in 1919.

Indications of oil have been observed at several localities along the belt, so that at some future date we may witness a wide extension of productive oil-fields over the oil-belt referred to above.

The Punjab.—Petroliferous beds of Eocene age underlie an extensive area in Northern Punjab, between Rawal Pindi and Shahpur. In 1915, for the first time, the mineral return from the Punjab included an appreciable amount of petroleum; this was from the newly-discovered field at Khaur.

The most recent information available regarding this field is that 10 wells have been drilled to a maximum depth of 1,650 feet, and that sufficient oil has been proved to warrant the erection of a refinery, which is now being built at Rawal Pindi, and is being connected with the field by a pipe-line 42 miles long.

Production of Petroleum in Punjab, in Imp. gallons

	1911.	1912	1913	1914	1915	1916.	1917	1918	1919.
Attock .	—	—	—	—	250,000	182,480	618,598	750,000	113,360
Mianwali	1,400	950	1,200	1,200	1,494	1,334	919	807	970

C. S. Middlemiss discusses the possible occurrence of petroleum in Jammu province. He says that the whole of the belt of stratified rock in Jammu embraces a section of the sub-Himalaya rocks of Tertiary age, from Eocene upwards, which are identified in composition, age and lithological character with those of the petroliferous series in the neighbouring

Rawal Pindi district. They are also identical in age with, but differ in some particulars lithologically from, the petroliferous series in Assam and in Burma, and also in the newly-discovered fields in Persia. In fact, they form with these known petroleum-bearing areas what is really one continuous but intricately-winding belt of deposits belonging to one comprehensive geological epoch, that stretches from Persia on the one hand to the extreme south of Burma on the other. It is also equally true that in general characters and in age these rocks exposed in Jammu agree with those of a great proportion of the more distant successful oil-fields of the world, notably with those of California, Peru, Russia, Roumania, Galicia and Sumatra.

Middlemiss, while examining the area, discovered the Nar Budhan dome, which he found to be strikingly similar to the Khaur dome, and he considers that it is the best place in the whole area for a trial boring.

Baluchistan.—Indications of oil occur at Shoran, 20 miles north of Gandava, in Baluchistan. In Sewestan, the lower Eocene limestones are petroliferous at various points, notably in the Khatan, Harnai and Spintangi districts. Oil-springs occur near the village of Moghal Kot, near the northern border of Baluchistan, and yield a yellowish coloured oil of specific gravity 0·815, containing about 85% of illuminating oil.

Between the years 1884 and 1891, various trial borings were put down by the Indian Government in the vicinity of the oil-springs of Khatan, in the Mari Hills, but although bore-holes were put down over 500 feet in depth, and a certain quantity of petroleum was found, the enterprise was abandoned in 1891, being regarded as a failure from a commercial point of view.

The Khatan oil-springs are situated at the end of a great, bare hill, formed of limestone beds bent into an anticlinal fold, which pitches towards the west. Apparently the springs consist of hot sulphurous matter accompanied by a thick, tarry material escaping from faults and fissures. The district has been examined by the Indian Geological Survey.

The total annual production of oil in India for the period 1908–1919 has been as follows:

Year.	Burma.	Assam.	Punjab.	Total.
	Tons.	Tons.	Tons.	Tons.
1908	693,611	12,972	2	706,585
1909	921,586	13,123	3	934,712
1910	846,031	13,283	4	859,318
1911	888 902	14,261	6	903,169
1912	981,341	14 990	4	996,335
1913	1,089 062	18,754	5	1,107,821
1914	1,018,612	18,754	5	1,037,371
1915	1,129,168	18,200	1,005	1,148,373
1916	1,167,076	20,948	735	1,188,759
1917	1,091,181	37 379	2,478	1,131,038
1918	1,099,338	43,999	3,003	1,146,340
1919	1,174,995	47,155	457	1,222,607
1920	—	—	—	1,000,000 [1]

[1] Estimated

As a result of trials regarding the relative merits of oil and coal as fuel for locomotives, the engines in the Karachi district of the North-Western Railway are being converted to enable them to burn oil instead of coal. Persian oil is imported for this service.

The imports of all kinds of oil into India during recent years have been as follow :

Year	Tons
1916	372,734
1917	289,677
1918	238,705
1919	372.737

The falling off in 1917 and 1918 was due to the scarcity of shipping facilities

Mesopotamia

(Mandated Territory)

The existence of petroleum and asphalt in Mesopotamia has been known since very early times. The oil-field in this country is only part of a petroliferous area which extends through southern Persia to the north end of the Persian Gulf, passes through Mendeli on the Turko-Persian frontier, and crosses the Tigris near El-Fatha. The oil zone follows the river to Mosul, and continues with interruptions to Zakho and the neighbourhood of Van, following the Bothan River.

This belt is approximately 1,000 miles long, and covers an area of more than 26,000 square miles.

Three main oil zones may be distinguished: the southernmost, on the Djebel-Hamrin, which starts at the oil wells of Mendeli and passes over El-Fatha to El-Hadr; the second, which connects Kifri with Tushurmatu; and the third connecting Kerkuk with Garadagh. If the latter is followed in its north-westerly direction it leads directly to the petroleum wells of Tel Kyara. The existence of an oil-belt may perhaps be assumed between the asphalt deposits near Hit, Nephata and Ramadi and the traces of oil in Basrah and Koweit. There are also numerous indications on the islands of the Persian Gulf.

Geologically, Mesopotamia must be considered a purely marine plain of recent Tertiary age, which has low mountain ridges running in several parallel chains from south-east to north-west, seldom exceeding 200 metres in height, and mainly consisting of sandstone. These ranges, which gradually decrease in height towards the north, broaden and pass into the alluvial plain to the south of Mosul.

The Tertiary rocks may be divided into two groups, the principal one consisting of sandstone, containing much gypsum, under which is found grey crystalline limestone belonging to the Lower Tertiary. Salt and salty clays are found in the gypsiferous strata and also in the sandstone overlying the gypsum. No dislocation of these Tertiary layers through eruptive dykes or sills is found in southern or in middle Mesopotamia, but to the north of Mosul large basaltic masses stretching from Djezireh to Diabekir have broken through the Nummulitic chalks of which the lower formation consists.

Near Mendeli there are thirty pits, none of which is more than about 10 feet deep. The oil, which is dark and thick, gives on distillation about 30% kerosene, the residue being used as fuel. About 300 tons of crude oil are refined annually in this district. In the Tushurmatu district the yield of crude oil is about 700 tons per annum. In the neighbourhood of Kerkuk, over an area of about 37 acres, there are about twenty springs giving an annual yield of approximately 300 tons of crude oil. The strata consist of red sandstones and red

saliferous marls with gypsum and intercalated beds of fresh-water limestone with *Cyclas* (Oswald).

The largest production is at present obtained from an area of about 246 acres near Tel Kyara, the annual production being about 1,500 tons. Near Zakho there are numerous seepages over an area of about 120 acres, which give a yield of from 250 to 300 tons per annum. Along the Euphrates River the asphalt deposits of Hit and Ramadi have been known from ancient times, the yield of asphalt from the wells near Hit being estimated at about 2.500 tons per annum.

PALESTINE

(*Mandated Territory*)

In Palestine, petroleum is found in the bituminous limestones of the Upper Cretaceous formation of the Dead Sea and the Jordan Valley, especially in the Lower Danian beds, which are very widely distributed. During the formation of the Jordan rift-valley, the liquid hydrocarbons reached the surface, and by evaporation and oxidation yielded abundant asphalt. The deposits of asphalt extend from the southern end of the Dead Sea, along its western shore, throughout the Jordan Valley to Lebanon, the chief localities being Wadi Mahawat, Wadi Sebbeh, and Nebi Musa, on the Dead Sea. Sulphuretted hydrogen gas is discharged at many points on the belt.

The asphalt deposits near Hasbeya, on the eastern slope of the Jubel-ed-Dahr (the mountain ridge separating the valley of the Hasbani from that of the Litani), are regularly mined. The output, which is about 380 tons per annum, is exported from Beyrout.

Oil issues from the cliffs facing the Dead Sea to the north of the confluence of the Nahr Zerka Ma River, and forms an iridescent film on the surface of the lake.

At several other points on the shores of the Dead Sea as well as of the Lake of Galilee and on each bank of the Jordan Valley, there are numerous hot springs bringing up traces of petroleum, emissions of inflammable gases, mud-volcanoes and deposits of bitumen.

AFRICA

British Cameroon

Petroleum is reported to have been observed on the Mongo a d Wuri rivers.

Egypt and Sudan

The Egyptian oil region lies between 27° 10′ and 28° 10′ latitude north, and between 33° and 35° 50′ longitude east, with outlying districts on the western and south-eastern borders of Sinai; it runs parallel to the Gulf of Suez and covers a width of from 3 to 12 miles. If the desert plain be included, the area of the region is approximately 3,000 sq. miles, extending from Ismailia to Ras Buras, with a maximum breadth of 30 miles.

Geologically, the fields resemble those of Persia, most of the petroleum having been obtained from the dolomitic limestones (Miocene), and from the sands (probably Nubian sandstones of Cretaceous age) underlying the gypsum. Hitherto no oil has been found in the lower Miocene limestones.

The structure of the region assumes the form of a system of rather sharply-flexured, asymmetrical anticlines, with intervening broader and more gently-flexured troughs. The axes of these folds are parallel and have a general trend somewhat north of north-west. The cores of the major anticlines are occupied by granite, porphyry, or schists, from which the sediments dip at 8° to 10° towards the south-west, and at 25° to 35° towards the north-east, and on the steeper sides of these arches, the beds near the apex are greatly reduced in thickness and show evidence of violent dislocation. The existence of secondary anticlines has also been proved. Thus the general structure is fundamentally one of overfolding with phenomena of pinching, production of monoclines and reversed faults. The resistant centre of the fold-system (originated in Middle Miocene times) was along the Gulf of Suez, as the steeper wave-fronts are turned towards it, both on the Egyptian and on the Sinai sides.

The smell of crude oil is noticeable in some of the upper

limestones at Gemsah, along the eastern flank of the Zeit Range near the sea, and especially in the decomposed saccharine limestone of North Zeit. At the foot of the Gharamal Range, oil is also found in a sandstone covering some low outliers.

Gemsah was the main producing area up to 1914, but since that date its output has greatly diminished, and commercial production is now practically confined to the Hurghada field.

Development work in Hurghada commenced in 1913. In October, 1914, oil was struck in large quantities at 1,670 feet, but the well sanded up and remained closed to the end of the year. The property now comprises a licensed area, 5 miles square, within which 23 wells have been sunk, 10 of which were productive in 1918.

The average monthly output for that year amounted to about 22,000 tons.

The concessions on Jubal and Ranim islands have an area of some six square miles. Five wells have been sunk on the Jubal Islands, and in each, gas and oil were encountered.

The total production of the two fields since 1911 has been as follows:

Year.	Tons	Year	Tons.
1911	2,793	1916	54,800
1912	27,962	1917	134,700
1913	12 618	1918	272,494
1914	103 605	1919	232,148
1915	34,961	1920	155,578

Other districts in which prospecting is being carried out are the west side of Gabal Zeit, Jaffatine Island, Ras Bahar (North of Gemsah), Gaysoon Island, Ras Dhib, and at Abu Zenina.

Storage tanks have been erected at Gemsah, Hurghada and Suez, with a capacity of about 100,000 tons, and at the last-named place there is a refinery capable of treating about 1,000 tons of crude oil per day. Pipe-lines have been laid to deep water at three shipping berths at Port Tewfik.

The crude oil varies in quality, but that found at Hurghada is a heavy oil with a paraffin base.

Typical distillation results are:

	Gemsah.	Hurghada.
Specific gravity at 62° F.	0·830	0·928
Benzine (below 150° C.)	23%	10%
Kerosene (150°–290° C.)	34%	14%
Fuel oil (above 290° C.)	43%	76%

The Egyptian Government are understood to have reserved certain areas, and a drilling programme is under consideration.

Early in 1918, Grabham and Thompson examined the Sudan coast. No surface indications of oil occur.

So far as the investigations have gone, the structures suggest two sites for boring, one of these being on Makawar Island, where an anticlinal fold occurs, and the other on the coast to the E.N.E. of Jebel Abu Shagara, where the crest of an anticline may be expected.

Gold Coast

Petroliferous lands are reported near the coast, in the neighbourhood of Appolonia and Birridaim. Wells have been sunk which prove the existence of various oil horizons, but no commercial quantities have so far been produced.

Nigeria

Indications of petroleum occur in Southern Nigeria, the surface formation consisting of sands and shales of the Tertiary series. With the assistance of the Nigerian Government, drilling was commenced in 1905 in the neighbourhood of the Oni River, Southern Nigeria. Six wells were sunk, but owing to difficulties in shutting off water, the operations were abandoned.

Extensive deposits of asphalt occur in the Ijebu district.

Somaliland

H. T. Burls in 1914 reported favourably on the prospects of obtaining oil at Agagwein, 28 miles S.E. from Berbera.

A geological expedition, undertaken in March, 1918, by Beeby Thompson and John Ball, reported the existence in the Daga Shabell area, near Berbera, of a small field of asphaltic oil, rich in benzine and apparently free from sulphur. A series of sedimentary deposits has been located over an area of many square miles, and in the lowest beds of the series oil-impregnated sands are found throughout a thickness of 800 feet. The bituminous sands are reported to be progressively rich in oil as the lowest strata are approached. The oil is said to be sweet-smelling, of high grade, and of light density.

A detailed examination of the field is being carried out.

South Africa

The oil possibilities of South Africa were investigated by Cunningham Craig in 1912. He reported that favourable geological structure is found only in a narrow belt at the southern edge of the Karroo System, although north-eastern Natal requires examination in this respect. He considered the Klipplaat area worthy of detailed examination, although he was not sanguine with regard to the prospects of finding oil there. As an outcome of this report, additional investigations were carried out in the Klipplaat district for the Geological Survey of South Africa by A. W. Rogers, who concluded that deeper boring south of the main outcrop of the Beaufort beds would not be successful in finding oil; that it is doubtful whether there is oil to be got from the northern area occupied by the Beaufort beds, and, finally, that there is insufficient evidence of oil under the Karroo to justify deep boring.

In the district immediately surrounding Port Elizabeth, the geological formation is said to be similar to that of the Caucasus belt, and it has been proposed to sink a test well about 20 miles from the town.

Traces of oil are reported to have been detected at various places in the Orange Free State, but the indications appear to be the result of igneous action on bituminous shales.

Traces of petroleum are stated to occur near the junction of the Limpopo and Umzingwani rivers in Rhodesia.

NORTH AMERICA

Barbados

Oil indications in the Scotland district, on the eastern side of the island of Barbados, have been found in the Tertiary strata, which is to some extent faulted and covered with coral limestone. At some places the coral beds are largely mixed with the debris of underlying strata, forming beaches which not infrequently conceal important geological structures and render the following out of pre-coral flexures very difficult.

Wherever the Scotland beds (Tertiary) are exposed, there is evidence of the existence of petroleum in the form of seepages of heavy oil, outcrops of oil-sand, and *manjak* veins; but unfortunately the Scotland beds are sharply and irregularly folded and denuded. Apparently the only hope of obtaining oil is to find localities where the above beds have been preserved from excessive denudation, and especially along the post-oceanic anticlinal flexures, which presumably involved the underlying strata. There appears to be every probability of moderate productions being obtained in the most favourable localities.

Fourteen wells have been drilled, but they do not seem to have been carried to sufficient depths. Only a small quantity of oil has been obtained from some of the wells. The oil is a fairly high-grade petroleum of asphaltic base and mobile. It contains a good percentage of light oils.

British Honduras

Indications of oil have been reported, and a geological examination is in contemplation.

Canada

The areas where oil indications are met with in Canada are very numerous.

Natural petroleum occurs in Ontario, New Brunswick, Alberta and British Columbia, but the only area where

regular production has, until recently, been obtained is Ontario, of which the principal districts are Mosa, Oil Springs, Petrolia, Bothwell, Tilbury, Moore Township, Sarnia, Dutton, Thamesville, Plympton and Onondaga.

The total production since 1901 has been as follows:

Year.	Tons	Year.	Tons.
1901	88,913	1911	41,585
1902	75,803	1912	34,762
1903	60,519	1913	32,583
1904	71,025	1914	30,686
1905	90,585	1915	30,781
1906	81,393	1916	28,303
1907	112,696	1917	30,547
1908	75,427	1918	43,534
1909	60,108	1919	34,352
1910	45,126	1920	28,134

New Brunswick.—Seepages of oil occur widely distributed in New Brunswick, especially where the Albert oil shales come to the surface in Albert and Westmoreland counties. For details concerning localities, etc., Vol. II of the *Petroleum and Natural Gas Resources of Canada* may be consulted.

A number of wells sunk in Westmoreland County proved a failure from a commercial point of view. A sample of oil, specific gravity 0·857, examined in 1902 by the Imperial Institute, gave the following percentages spirit, 5·6; kerosene, 28·3; heavy oils and solid hydrocarbons, 58·2; water, 7·9. The percentage of solid hydrocarbons is unusually high.

In the Stony Creek field, Albert County, the gas and oil horizons are confined to the Albert series, which consist of thinly-bedded limestones and dark shales, with intercalated petroliferous sandstones of Lower Carboniferous or Upper Devonian age. Five groups of productive gas and oil-sands have been proved. In some places the strata of the Albert series are nearly horizontal, whilst elsewhere they display folding and faulting. By 1913, 33 wells, ranging from 1,200 to 2,060 feet, had been drilled. The Albert series have now been proved to have a maximum thickness of 2,700 feet. In 1917 a gusher was brought in having an initial flow of 10,000 barrels a day, which was, however, not maintained. The production of petroleum in New Brunswick from 1910 to 1919 varied from about 1,000 to 4,200 barrels per annum.

Quebec.—There are indications of oil on the Gaspé Peninsula. Several wells have been drilled in this area, but most of them were practically dry; the best well only produced in all about 2,000 barrels of oil. The prospects of obtaining oil in profitable amount are not hopeful. There is an absence of any well-defined petroliferous beds, though oil does occur in small quantity in isolated lenticular oil-sands; there is an abundance of salt water; the rocks are sharply folded and faulted and igneous intrusions are of frequent occurrence.

Ontario.—Most of the oil in commercial quantity is obtained from the Onondaga limestones (Devonian); the most successful areas lie along the axis of the Cincinnati anticline, a great fold extending northwards from Tennessee through N.W. Ohio, where it is extremely productive, and thence across Western Ontario, from near Littles Point on Lake Erie to near Kettle Point on Lake Huron, passing N.30°E., through Essex, Kent and Lambton counties.

The production in barrels (35 Imp. gal.), from 1913 to 1919, is shown in the following table:

	1913.	1914.	1915	1916	1917.	1918.	1919.
Lambton County (Petrolia and Oil Springs) .	155,747	154,186	161,368	142,208	132,523	120,358	124,180
Kent County (Bothwell and Tilbury-Romney)	61,172	52,491	46,137	50,153	39,723	54,341	47,790
Brant County (Onondaga) . .	4,172	2,437	1,490	1,617	382	1,183	197
Elgin County (Dutton) . .	4,610	2,190	5,401	2,852	2,941	1,876	1,272
Belle River .	464	1,191	46	47	—	448	—
Middlesex County (Mosa Township)	—	—	—	—	20,998	108,990	45,860
Thamesville .	—	—	—	—	6,420	1,568	801
Totals. .	226,165	212,495	214,442	196,877	202,987	288,764	220,100

The production in 1907 was more than three times that of 1913. From 1913 to 1916 there was a more or less steady decline, but the outputs of the last three years show an average improvement. This was due to the production of oil in the new fields of Mosa Township and Thamesville.

Saskatchewan.—Several wells have been drilled on the plains of Saskatchewan by prospectors in search of oil, and at various places rocks have been penetrated containing natural gas in small quantities. It is possible that certain local undulations in dip of the Cretaceous strata may yield a certain amount of oil if these folds could be located. In 1915 some deep borings put down in the region of South Saskatchewan River, yielded large volumes of gas from an arenaceous member of the lower Benton series.

Alberta.—In Southern Alberta, west of Calgary, lies the foothill country of the Rocky Mountains. Here, according to Bosworth, the sedimentary formations are thrown into a series of successive sharp folds, the plication becoming more intense as it proceeds. It is amongst these folds that the majority of the wells are being drilled, and that small amounts of oil and, in some cases, large quantities of gas, have been obtained. The foothill belt is characterized by steep folds, often overturned, thrusts, faults and a generally complicated structure. Only in the outermost folds, i.e. on the eastern side, are simple anticlines found. Most of the oil indications have occurred in the Dakota and Kootanie formations (Cretaceous), and the small quantity of oil produced by the Dingman well, during the boom of 1912–14, came from a coal-bearing series, probably belonging to the Kootanie.

The Dakota beds have a thickness of 1,000 feet, and consist of hard sandstone with some shale bands. They are covered by dark shales, and lie over the Kootanie beds, 375 feet in thickness, consisting of dark shales, sandstone and important coal seams. Below the Kootanie beds are dark shales of Jurassic age.

All the rocks of every formation outcrop at the surface, yet there are no seepages of oil, which strongly militates against the possibility of the occurrence of any large quantity of oil in the region.

Of the many wells drilled in Alberta, during the four years prior to 1917, there are said to be nine in which oil has been found. Two companies have undertaken refining operations on a limited scale, and wells are being deepened to seek a greater supply of oil. Actual production, although not

of much importance, shows that some progress is being made, the figures for 1918 being about 1,863 tons compared with about 1,214 tons for 1917.

In Northern Alberta the "tar sands" (Cretaceous) occur geologically below shales and rest on limestone (Devonian). They represent a sandstone formation more or less completely saturated with heavy oil or bitumen. The tar sands form cliffs, sometimes 200 feet or more in height, which are exposed for about 100 miles along the Athabasca River, and are black in colour and plastic. Experiments carried out by Bosworth show that the rock contains some 14 gallons of petroleum per ton, of which 5 % is gasoline. Assuming that the tar sands maintain a constant character over an area of 10,000 square miles, the quantity of petroleum available would be nearly 200,000 million tons.

It is generally believed that the Devonian is the petroliferous formation from which the Cretaceous tar sands have derived their bituminous contents, and that the particular source of the oil is a bed of black shale, several hundreds of feet in thickness, interbedded with the Devonian rocks. Between 1894 and 1898, three wells, drilled by the Government, struck gas. Tar rock was reached at 1,750 feet, and penetrated to a depth of 87 feet, when thick tar was forced up by the gas, and drilling became impossible. Various private wells have been sunk in the region. Some of these have encountered gas, and others, oil in small quantities. Drilling in this district was reported in 1918 to have been discontinued, but efforts are still being made to extract oil from the tar sands.

North-West Territories.—Indications denoting the presence of oil occur on a large scale along the Mackenzie River; and on the shores of the Great Slave Lake seepages of oil are found at numerous points. Inland, there are pools of heavy oil and deposits of asphaltum. According to Bosworth, the source of the oil is a bituminous shale containing palæozoic plants (Devonian), which is associated with a great thickness of bituminous limestone, and the oil is accumulated in overlying sand formations and porous dolomites.

These territories are remote from civilization and covered by dense forest and muskeg; but, for several years past, the

Imperial Oil Company has been drilling at Fort Norman, at the junction of the Great Bear and Mackenzie rivers, has staked out about nine miles on each side of the latter river, including the islands, and has eleven oil-rigs in operation. Early in October, 1920, a flow of high-grade oil, estimated at about 500 barrels per day, was struck in the well at Fort Norman at a depth of 800 feet

This discovery has caused a great deal of excitement, and will no doubt lead to greatly increased prospecting for oil in the near future, both by private individuals and by companies.

It has been reported that the proximate analysis of the crude oil is as follows: Gasoline, 22·5%; illuminating oil, 38·5%; light lubricating oil, 33·9%; and medium lubricating oil, 4·1%. It is stated that a small refinery will be erected at Fort Norman for supplying petrol for aeroplanes and motor-boats.

British Columbia.—Owing to the disturbed geological conditions, opinions differ as to the extent of natural oil deposits, of which there are indications on the coast.

Newfoundland

Indications of petroleum have been found on the shores of Parsons Pond, a stretch of salt water in bay formation, lying between St. Pauls Bay and Portland Creek on the north-west coast, facing the Gulf of St. Lawrence; attempts at development have not proved a commercial success, but they have recently been resumed A small production is obtained from three wells by pumping.

Trinidad

Petroleum in Trinidad is practically confined to the southern part of the island along several more or less clearly defined parallel anticlines running from east to west, and all land south of latitude 10° 26′ 36″ N. has been officially declared oil-bearing. The principal producing area is the Forest Reserve, near Brighton. Other districts are Mayaro, Guayaguayare, Tabaquite and La Brea. There are three

tenures of land: (1) Crown land, on which oil is the property of the Crown; (2) alienated land, where oil is also the property of the Crown, although the surface rights are in private hands; and (3) private land, where oil is the property of the landowner. During 1920, 53,404 feet were drilled on Crown lands as against 23,972 feet on private lands, the number of new wells drilled being 44 on Crown and 23 on private lands, bringing the total number of wells drilled in the colony to December 31, 1920, to 523, of which 313 were on Crown lands.

The southern range of hills, which follows the southern coast, is of Tertiary origin, with here and there pre-Tertiary inliers projecting through the newer rocks. The Tertiary rocks are estimated to be from 6,000 to 6,500 feet thick, and consist chiefly of clays, sands and marls. The upper oil horizon, known as La Brea sands, from which the well-known pitch lake is derived, is exposed in the neighbourhood of La Brea. At from 1,400 to 1,500 feet in depth appears the second oil-bearing belt, the Rio Blanco oil-sand, and at a farther depth, at from 3,600 to 4,000 feet, is the Galeota petroliferous group. A still lower horizon is reported in the neighbourhood of Tabaquite, but this may in reality be a member of the Galeota sand. A feature of the petroliferous area is the mud volcanoes which are of varying sizes and give evidence of widespread gas pressure.

All the sediments, constituting the three main horizons, are very prone to great variation in character when traced from point to point. Lateral variations and current-bedding give rise to many irregularities in dip, strike and lithological characters of the individual members of the series. The folds of the oil-bearing and associated beds display many disconcerting variations in structure. One and the same fold may be asymmetrical at one point, nearly symmetrical at another, whilst the axis itself may experience frequent changes in direction and pitch.

The pitch lake has an area of about 100 acres, and there is a constant stream of pitch towards the sea averaging from 15 to 18 feet in depth. The working of the lake deposit, of which large quantities are exported annually, is in the hands of a company. It is estimated that the lake contains 158,400

tons of pitch for each foot of depth, which with an average depth of 20 feet would give a total of 3,168,000 tons.

Numerous oil gushers have from time to time been obtained, principally from the upper horizon, production from the lower horizon being impeded by shifting sand, which tends to crumple up the casing and choke the bore-hole. It is hoped, however, that an effective remedy will be found for this difficulty.

Most of the oil has an asphalt base, that from the lower sands being much lighter than that produced from the shallow sands. At Tabaquite an oil of paraffin base containing about 30% benzine is found.

The following table gives the results of laboratory tests made on samples taken from bulk shipments of crude oil from some of the principal producing areas in Trinidad :

	Forest Reserve.	Tabaquite	Brighton.
Petroleum spirit	8·1%	28·6%	6·0%
White oil or kerosene	7·1%	12·6%	3·1%
Fuel oil and loss	84·5%	58·8%	90·9%
Specific gravity of crude at 15·5° C	0·926	0·808	0·951
Flash-point of crude	59° F.	Below 45° F.	74° F.

The production in Trinidad since 1911 has been as follows:

Year	Tons	Year	Tons.
1910–1	17,516	1916	129,903
1911–2	39,943	1917	224,324
1912–3	70,506	1918	291,489
1913–4	90,092	1919	257,746
1914–5	147,015	1920	297,588
1915 (9 months)	93,957		

In 1918 the chief producing company had a production of 154,179 tons, or more than 50% of the total output of the Colony. The next largest outputs were 83,054, 18,282 and 16,478 tons respectively.

Pipe-lines run from the fields to the ports of shipment—Brighton, Pointe à Pierre, Point Fortin and Claxton Bay.

Exports since 1912 have been as follow:

Year.	Tons.	Year	Tons.
1912–3	17,183	1917	151,112
1913–4	54,281	1918	182,757
1914–5	48,769	1919	196,876
1915 (9 months)	57,140	1920	142,375
1916	136,620		

Local industries are turning their attention to oil fuel as a substitute for coal, and the Government railways have converted some of their locomotives to oil firing.

SOUTH AMERICA

BRITISH GUIANA

There have been frequent reports of the existence of petroleum deposits in British Guiana, particularly in the north-west in the region of the Waini River. Several exploration licences have been granted, but so far as is known no results have been obtained. Negotiations have been in progress for a concession granting exploration rights over 2,000 square miles, with the option of choosing therefrom an area of 100,000 acres for final prospecting and development, if the results of a geological investigation should be favourable. A detailed geological survey of the area is being carried out.

AUSTRALASIA

AUSTRALIA

Although efforts have from time to time been made to locate deposits of natural petroleum in Australia, no success has yet been attained.

In Queensland test wells have been sunk, although geological reports have hitherto not been favourable to the existence of free petroleum. It is considered by some experts, however, that the wells have not been sunk deep enough to make the tests conclusive, and further trials are now being carried out at Roma, in the north-east of Maranoa province, where a considerable flow of gas has been struck.

In New South Wales the Industrial Boring Company put down a bore during 1919, on a site near Penrith, to a depth of 2,600 feet.

The Commonwealth Government has offered a reward of £10,000 for the discovery of natural oil in commercial quantities in Australia, and a bonus of £5,000 has been offered by the South Australian Government to the person or company that first obtains 100,000 gallons of crude petroleum from a

well situated in South Australia, the oil to contain not less than 90% of products obtainable by distillation.

PAPUA (NEW GUINEA)

In British New Guinea evidences of petroleum occur along a coastal belt some 8 to 12 miles wide, from the delta of the Purari River almost to Yule Island, surface indications being dotted over an area of about 1,500 square miles.

In 1919 the British and Australian Governments agreed to co-operate in order to develop this territory. Several wells had been previously sunk in order to prove whether oil existed, these experimental borings being based on a geological survey carried out by Arthur Wade. Fair shows of oil were met with, but considerable difficulty was encountered in drilling through the soft Tertiary formation, which caved badly while drilling was in progress.

The official record of results shows that two of the bore-holes yielded gas only, four gave a small production of oil, while No. 7 well struck oil at 185 feet, with a flow of 25 gallons per day.

The strata appear to be of Miocene age, consisting of a series of mud-stones and sandstones, with occasional thin bands of limestone.

The British and Australian Governments have now handed over the whole work of prospecting in Papua to the Anglo-Persian Oil Company as their agents

The Anglo-Persian Oil Company, on taking over the work, decided that further geological investigation was necessary, and sent out an expedition which is making a detailed survey. This has indicated that favourable results might be expected by drilling, not in the Upoia district, but in the oil-belt further to the east, which has been hitherto untested, and where a promising anticline has been located.

The sample of oil from this field, examined at the Imperial Institute in 1913, had a reddish-brown colour and a specific gravity of 0·802. On distillation the crude oil yielded:

	Per cent.
Petroleum spirit	32·5
Kerosene	58·7
Lubricating oils and solid hydrocarbons	8·8

In late German New Guinea, oil indications exist between Eitape and Beaken Bay, the principal being near Amuloi on a tributary of the Halikamak River, which enters the sea east of Smein village, 60 miles from Eitape, and also near the village of Matapau, about 2 miles from the mouth of the Wakip or Tiain River, which enters the sea about 40 miles east of Eitape.

A rough survey of this area has shown the principal formations to be alluvial deposits of gravel, sand and clay, outcrops of hard slaty clay, and sandstone varying from fine-grained to coarse material, running into grits, conglomerates, breccias and limestone.

The indications near Matapau are the most important, excavations showing the whole surface, sand and gravels, to be heavily saturated with oil, which appears to be of paraffin base. It is dark brown in colour, a good rust solvent and lubricant, and burns with a reddish flame.

New Zealand

Indications of oil have been found in Taranaki province, North Island. The superficial deposits of andesite lavas and fragmentals and recent sandy debris, shroud the sedimentary rocks, which consist of claystones, sandstones, and fine conglomerates ranging probably from Pliocene to Miocene age, for a radius of about ten miles from Moturoa. Beyond this, to the east and north-east of Moturoa, the sedimentary rocks appear at the surface as alternating beds, and are traceable to Mohau, 50 miles from Moturoa, the beds passing downwards, probably conformably, into limestones, claystones and sandstones, with coal seams. Structurally these rocks seem to form part of a great monoclinal fold, dipping from Mohau towards Moturoa, with minor cross-structures in the form of anticlines and synclines of sufficient importance to have influenced the position of subterranean reservoirs of petroleum.

A large number of holes have been drilled to depths of from 2,000 to 5,000 feet, but so far without any commercial success, although oil has been obtained in small quantities. Fur-

ther efforts are being made to develop the field with Government assistance. Operations have also been carried out in the Gisborne and Wairarapa districts, North Island, and at Kotuku and Chertsey, South Island. At Kotuku small flows of oil have been obtained at shallow depths, but so far no wells have given profitable results.

CHAPTER III

SOURCES OF SUPPLY OF PETROLEUM (*continued*)

(*b*) FOREIGN COUNTRIES

EUROPE

Galicia (Poland)

The oil-bearing territory of Galicia extends from the borders of Bukowina in the east across almost the whole length of the country to the Silesian frontier on the west. It may be conveniently divided into three main sections:

The eastern area—comprising the districts of Stanislawow, Kolomea and Kosmacz.

The central eastern area—including the Boryslaw, Tustanowice and Mraznica fields.

The western area—extending through Lisko, Sanok, Krosno, Jaslo and Gorlice as far as the frontier of Silesia.

Seepages of oil in various parts of Galicia have been known for many years, and exploitation by means of hand-dug wells took place at Bobrka as far back as 1850. After the introduction of mechanical drilling, development was very rapid, oil being found in quantity in the first instance at Sloboda-Rungurska and subsequently at Schodnica and Potok.

The oil occurs in rocks of—

(1) Lower Oligocene age, as in Boryslaw, Tustanowice, Rypne, Perchinska, etc.

(2) Cretaceous age, as in Kosmacz, Grabownica, etc.

(3) Eocene age, as in Boryslaw, Tustanowice, Sloboda-Rungurska, etc.

The geology is very complex, being characterized by sharply-compressed, irregular, overthrust folds, and in some

places by serious faulting. The Eocene, which is very persistent, yields the largest supplies of oil. Lithologically, the rocks are largely shales and sandstones, with, occasionally, conglomerates, and, more rarely, limestones, but the sequence of the series is rendered inconstant by unconformities of greater or less importance, and beds of identical character occur at different horizons, whilst contemporaneous deposits in adjacent regions show considerable differences in character. The anticline of the Boryslaw field is an asymmetrical fold, which is considerably faulted along both the strike and dip, and pitches towards the east. The older formations are thrust over the productive Oligocene beds.

The richest fields that have so far been discovered and exploited are those of the Boryslaw-Tustanowice area, which began to produce in 1901, and have continued till the present day to yield about 90% of the total annual output of Galicia.

Production reached its high-water mark in 1909, when the total output exceeded 2,000,000 tons, 92% of which came from the Boryslaw-Tustanowice field. Since that time the production has steadily declined, owing to the natural exhaustion of many of the wells and more particularly to the influx of water which began in 1911 in the Tustanowice area.

The total Galician production from 1900 to 1920 has been as follows :

Year.	Metric tons.	Year	Metric tons	Year.	Metric tons.
1900	326,334	1907	1,175,974	1914	655,614
1901	425,200	1908	1,754,022	1915	670,942
1902	576,060	1909	2,086,341	1916	927,440
1903	726,971	1910	1,762,560	1917	901,910
1904	827,117	1911	1,458,275	1918	678,640
1905	801,796	1912	1,187,007	1919	818,333
1906	727,239	1913	1,113,400	1920	752,528

Speaking generally, the damage suffered by the Galician oil-fields during the war was relatively small. Some properties were damaged by the Austrians to prevent their falling into Russian hands, but the greater part of the destruction that took place was due to the Russians, who, on retiring from Central Galicia in May, 1915, burnt down about 200 wells in Tustanowice and destroyed a considerable number of steel tanks at Boryslaw. The Maryampol refinery was also demolished

at this time. In 1917, when the Russians finally retired from East Galicia, they also destroyed a part of the refinery and tank farm at Peczyniczyn.

On the re-occupation of the fields by the Austrians, with the help of the Germans they made great efforts to re-establish the industry and increase the output. The production of the whole of Galicia, however, was in January, 1920, considerably less than half that of 1909. This was due in some measure to lack of machinery and other necessary plant; when these are forthcoming and drilling begins again in earnest, there is every reason to believe that the production may rise to something like the pre-war level.

The present production of Eastern Galicia is about 3,000 tons a month, and that of the western fields between 4,000 and 5,000 tons. In the latter area there are about 1,000 producing wells, a quarter of which, giving rather more than half the total production, belong to French interests. The following figures show the production of the Krosno-Jaslo district since 1910:

Year.	Metric tons	Year	Metric tons.
1910	65,323	1915	33,547
1911	63,345	1916	61,116
1912	59,528	1917	51,854
1913	66,905	1918	57,651
1914	57,512		

It has been estimated that 1,500,000,000 kronen are invested in the oil industry of Galicia, and that at the end of 1918 this was held approximately as follows:

	Per cent.
Germans and Austrians	55
French	20
British	15
Poles	5
Other nationalities	5

Since the termination of the war, however, the French and Belgians are reported to have extended their interests considerably.

The greater part of the Galician crude oil is refined in the country, principally in Drohobycz, where the State refinery and two other refineries are able to treat about 500,000 tons

annually. There are large refineries also at Limanow, Trzebinia, Glinik Maryampolski, Jaslo, Krosno, Jedlicze, Ustrzyki, Lwow and Peczyniczyn, and numerous smaller ones in various parts of the country. The estimated total yearly capacity of the Galician refineries is about 1,000,000 tons. Before the war more than half the refined products were exported to Germany and Austria-Hungary.

According to recent statistics, there are about 8,000 workmen engaged on the various Galician oil-fields, most of them being recruited from the Polish peasants of Western Galicia. The Ruthenian element among the oil workers does not appear to exceed 2 or 3%.

The technical difficulties of drilling in Galicia are very considerable, owing to the geological formation of the oil-fields, whose structure is said to be the most complicated in the world.

The obstacles due to these intricate geological conditions were for long enhanced by the difficulty of obtaining good casing, and it was only after the introduction of the Canadian system of drilling by W. H McGarvey that progress began to be made. With the old one-metre-square hand-dug wells a depth of about 320 feet could be attained, and with the cable drilling system about 650 feet; but, by the adoption of a modified Canadian system, wells have been drilled to a depth of nearly 5,000 feet. In 1913 there were, in fact, in the Boryslaw-Tustanowice district alone, 252 wells over 4,000 feet deep.

The crude oil of the Boryslaw field forms the standard grade for Galicia. It is of good quality, with specific gravity from 0·850 to 0·860, and yields all the usual commercial products, including from 6 to 10% benzine, from 30 to 35% kerosene, about 20% lubricating oils, and 6 to 7% wax. Its colour varies from light green to dark amber and black. Bitkow, in East Galicia, yields a light grade oil with specific gravity of 0·760 to 0·770, and a benzine content in some wells of 60 or even 70%.

Many of the wells in Western Galicia, e.g. the shallow wells of the Brzozow-Grabownica district, also yield an oil with a very high benzine content, not infrequently over 50%.

There are numerous gas wells in Galicia, more especially

in the central fields, though several rich wells have recently been drilled in the neighbourhood of Menczinka, in Western Galicia, one of which yields from 7,000 to 10,000 cubic feet of gas per minute.

According to Austrian law, which is still in force, oil deposits in Galicia are the property of the landowners, who are free to dispose of the rights of exploitation. The usual lease is for a period of 25 years, often with the option of prolongation for 10 years. The proprietor of the land receives a production royalty, which varies from 6 to 18% in Eastern and Western Galicia, and from 20 to 22% in the Boryslaw district. Much speculation takes place in the sale of shares in these production royalties, which are known as "bruttos," and are constantly changing hands in the market.

At the present time the Galician oil industry is labouring under great difficulties, which are enhanced by the unsettled political condition of the country. Working material is almost unprocurable, the wages demanded by the workmen are very high, and the cost of refining has increased greatly on account of the high price of coal. With the return of normal conditions, however, there appears to be little doubt that production will increase and the industry recover much of its former prosperity. There are said to be extensive fields that have so far hardly been exploited at all, and much deep-drilling may still be profitably carried out in districts already partially exploited. Areas which are considered capable of great development are situated in the districts of Kolomea, Nadworna and Dolina in Eastern Galicia, and in the neighbourhood of Sanok, Krosno, Jaslo and Brzozow in the west. Drilling in the eastern part of Galicia is generally much deeper than in the western, where 2,300 feet is considered to be about the maximum depth.

Bukowina.—A broad belt of Neocomian and Cretaceous rocks crosses the Bukowina in South-Eastern Galicia from south-east to north-west, and is thrown into a series of folds. It is stated that the Neocomian shales are oil-bearing in the three principal anticlinal members of these folds. Several wells have been drilled in the Watra Moldawitza district.

GERMANY (INCLUDING ALSACE)

Oil has been found for many years at Wietz and other places around Hanover (Prussia), Tegernsee in Bavaria, and Pechelbronn, Ohlungen and other localities in Lower Alsace, the Prussian and Alsatian fields being the most important. In the Prussian fields the oil is associated with Mesozoic strata, and is said to come chiefly from limestone and sandstone belonging to the Upper Jurassic, or to transitional beds between the Jurassic and Cretaceous formations. From shallow depths the oil has a specific gravity of 0·940, but at greater depths it becomes lighter.

In Bavaria the oil is found in Eocene marls and sandstones, the specific gravity being about 0·812; in Alsace in thin seams of sandstones and sandy shale of Tertiary and Mesozoic age; Pechelbronn, the principal field, yields an oil of specific gravity of 0·880. The oil from Ohlungen is somewhat lighter and contains a considerable proportion of solid hydrocarbons.

The wells, as a rule, are long-lived, though their production is not large.

Production (so far as the figures are available) has been as follows:

Year	Alsace.	Other districts	Total.
	Metric tons	Metric tons	Metric tons.
1901	19,997	24,098	44,095
1902	20,205	29,520	49,725
1903	20,947	41,733	62,680
1904	22,016	67,604	89,620
1905	21,128	57,741	78,869
1906	22,154 [1]	59,196	81,350
1907	26,124 [1]	80,255	106,379
1908	28,898 [1]	113,002	141,900
1909	29,726 [1]	113,518	143,244
1910	—	—	145,168
1911	—	—	142,992
1912	—	—	144,961
1913	—	—	140,000 [2]
1914	—	—	140,000 [2]
1915	43,176	—	—
1916	—	—	—
1917	46,911	—	—
1918	50,000	130,000	180,000 [2]
1919	47,225	32,775	80,000
1920	54,910	30,000	84,910

[1] Includes Bavaria. [2] Estimated.

The Alsace field was at first worked by drainage, by means of a system of galleries, but subsequently boring operations were carried out. Plant has also been installed for washing the bituminous sand, the oil from the field being treated in refineries at Pechelbronn, Soultz, Biblisheim and Durrenbach. Recently a well has been brought in near Pechelbronn yielding about 30 tons of petroleum daily.

In 1916, on the advice of Paul de Chambrier, an attempt was made at Pechelbronn to drive galleries into a bed already exhausted by borings The results are said to have surpassed all expectations. In one district the oil obtained by galleries amounted in 3½ years to 51,080 tons, as compared with 21,000 tons in 10 years from drilled wells.

A recent attempt to find petroleum in the Oldenburg district, near Bloh, has been successful.

GREECE

Oil indications occur along the west coast of Greece at Kyparissia, Messenia province, at Kyllene (opposite the island of Zante), in the Paxos and Corfu islands, near Argos and Janina, in Epirus, and along a line from Jania to Selenitza in Albania. A boring by the Greek Government in 1893 at Kieri, in the island of Zante, yielded a small quantity of crude oil mixed with salt water; this well was abandoned, but subsequently 4 wells were sunk by a French syndicate, and a yield of about 40 tons of crude oil per annum has been obtained since 1914

HOLLAND

The only evidence of the possible existence of petroleum in Holland has been afforded by the discovery of natural gas at Velsen, province of Overijssel. The quantity yielded, however, is quite small—about 500 cubic feet per hour.

ITALY

The principal districts containing oil indications are in North and Central Italy.

In North Italy the Emilia zone, covering the districts of Parma, Piacenza, Bologna, Modena and Reggio, has produced oil for many years, the productive formation being in strata of various ages—Eocene, Miocene and Pliocene.

Indications have also been reported around Pavia in Lombardy, and in 1914 two prospecting licences were granted covering the districts of Retarbido and Revanazzano.

In Central Italy the oil zone is approximately midway between Rome and Naples, and extends from Gaeta on the west to Cherita on the east. It is divided by the Apennine Mountains into two basins, Ceprano on the west and Abruzzi on the east. Little has been done in the east owing to the disturbed geological conditions; oil has, however, been found in the Ceprano basin, in the west, where the geological formation is well defined by the outcropping of petroliferous rocks. Here the oil occurs in Miocene and Eocene strata, and is believed to be connected with deeper reservoirs. A small production has been obtained at San Giovanni d'Incarico, Caserta province, at a depth of 1,300 feet, and tests are also reported at Pilsa, near Gaeta.

In Sicily there are deposits of bituminous clay near Basia (Messina), in the Alcantara Valley, near Nicosia and Ravenusa, and also deposits of asphaltic and bituminous limestone near Ragusa.

The total production of Italian crude oil for the years 1901–1920, has been as follows:

Year.	Metric tons	Year	Metric tons	Year	Metric tons.
1901	2,246	1908	7,088	1915	6,105
1902	2,633	1909	5,895	1916	7,036
1903	2,486	1910	7,069	1917	7,000[1]
1904	3,543	1911	10,390	1918	7,000[1]
1905	6,123	1912	7,479	1919	5,320
1906	7,451	1913	6,564	1920	5,400
1907	8,327	1914	5,542		

[1] Estimated.

ROUMANIA

The petroleum region of Roumania seems continuous from the Serbian frontier on the Danube to the Bukowina, the

principal producing areas being Prahova, Dambovitza, Buzeu and Bacau. Of these, Prahova is the most important (producing about 85% of the total output), its chief fields being Moreni, Bustenari, Campina, Baicoi and Taintea.

The oil occurs principally in the Miocene and Pliocene series, but the Eocene and Oligocene contribute largely to the total production, and the Neocomian and Cretaceous rocks may eventually prove to contain valuable stores of oil. The strata consist chiefly of marly shales alternating with beds of sand or sandy clay, and occasional seams of pebbles. Limestone and compact sandstone are less frequently found. Gypsum and rock-salt are common, and apparently present in every part of the series. The fields are characterized by narrow, sharp and eccentric folding, and in places, as at Moreni, by much faulting.

Extensions of the Bustenari field to Bordeni in the south, of the Moreni field to Doichesti and Bana, and of the Baicoi field as far as Ferbatori, have already been proved, together with a new field at Ochiuri in the Dambovitza area.

The Roumanian production for the years 1910–1920 has been as follows:

Year.	Metric tons	Year	Metric tons.
1910	1,352,289	1916	1,244,093
1911	1,544,072	1917	517,491
1912	1,806,942	1918	1,214,219
1913	1,885,225	1919	905,064
1914	1,783,947	1920	1,017,382
1915	1,673,145		

The main refining centres are Campina, Ploesti, Buzau and Tergoviste.

There is storage available to the extent of about 1,765,000 tons, and a system of pipe-lines connects the fields with Constanza. During the German occupation of the country the pipe-line to Constanza was interrupted and the oil traffic diverted to Giurgevo by lines which crossed the Danube at Cernavoda.

When the German invasion of Roumania took place in 1916, considerable damage was done by a British Military Mission to the wells, plant and stocks of oil. The Germans worked energetically to restore the output, and in July, 1917,

obtained a production of approximately 1,470 tons per day, this being increased at the time of the Armistice to about two-thirds of the pre-war production.

The deposits are worked by numerous companies of various nationalities, including British, French, American, and Dutch.

The reconstruction of the Roumanian oil industry has been a task of great difficulty, owing to shortage of plant and disorganization of transport, which, until quite recently, prevented the export of petroleum products on any large scale. This resulted in the accumulation of stocks, with consequent decreased production. The high cost of living, moreover, resulted in labour disturbances, which impeded considerably the re-establishment of the industry.

Russia (including Georgia)

The principal oil-bearing regions of Russia are the Caucasus and Ural-Caspian, deposits being found in shaly marls and fine-grained calcareous sandstones in frequent alternations, the sandstones varying from hard rock to practically loose sand. The age of the principal oil-bearing beds is Miocene, and the deeper wells extend into the Oligocene formation.

In the Ural-Caspian region, indications have been found over an area of about 60,000 square miles, extending from the mouth of the Emba River northwards to Alexandrovsk Gai, and east to Yemir. So far, however, oil in commercial quantities has only been found at Dossor, the production being about 2½% of the total Russian output (in 1916 it was about 260,000 tons).

In the Caucasus, the principal districts are: (*a*) Baku, on the Apsheron Peninsula, including the fields of Balakhany, Saboontchi-Romany, Surakhany, Bibi-Eibat and Binagadi; and (*b*) the Grosny district, including the Belik extension, situated on the northern slopes of the Caucasus.

According to A. Beeby Thompson, the oil-bearing strata of the Apsheron Peninsula, on which the Baku oil-field is situated, are covered in many places by a local series of beds, composed mostly of yellow sands and highly fossiliferous limestones, which, apparently, lie conformably over the oil

series. The latter are composed of grey, blue-grey, and green-grey clays, several variations of sand that are grey when washed, but often darkly discoloured with oil when raised, and sandstones, many of which are calcareous and sparingly fossiliferous. The Baku formations are supposed to belong to the Oligocene and Lower Miocene ages. The oil is distributed in belts or zones. In the Saboontchi-Romany district, no less than eight highly-productive belts have been discovered, and in the Bibi-Eibat field, five. The beds of oil-sand are of erratic and irregular occurrence, probably due to the existence of lenticular pockets, which swell out in one direction and then in another, and are not necessarily connected.

The anticline of the Grosny oil-field coincides approximately with the formation of the hills, whose trend is from north-west to south-east. The petroliferous beds reach the surface about the neighbourhood of the Mamakai region, but in both directions from this point the productive beds become deeper. The slope of the anticline on the north side is exceedingly steep, whilst that of the south side is gentle.

Several deep borings put down on the north side have failed to penetrate petroliferous strata, which may be due to a fault or to complex folding on that side. The strata are unlike those of Baku, for not only are the deposits highly impregnated with lime, which imparts to them a marly character, but the well-defined, highly-petroliferous loose sands, so prevalent in Baku, are quite absent, and in their place are found sandy strata which, when washed, display little indications of oil. The Grosny oil strata are not nearly so prolific as those of Baku, for the wells dry up, as a rule, after a brief period of spouting or fair bailing. Five productive belts have been discovered in the field.

There does not appear to be any evidence in the Russian oil-fields that the synclines are not as productive as the anticlines.

The surface of the Ural-Caspian region is occupied by the recent deposits of the Caspian Sea. Permian rocks underlie the whole of the petroliferous area, but are only occasionally exposed as inliers. Unconformably upon the Permian lie Jurassic, followed by Cretaceous rocks. The Tertiary

formation is only sparingly represented at a few points. The complicated system of flexures is probably the result of the two sets of movements, one of which produced the Ural Mountains and the other, the Caucasus Mountains.

The oil from Dossor has a specific gravity of about 0·855; from Karatchungal, 0·846; from Karaton, 0·867; and from Guriev, 0·882. Trial distillations at the refinery at Rakusha in 1914 gave the following percentages: Gasoline, 0·36; kerosene, 23·66; residues, 74·92; loss, 1·06 The crude oil from Dossor contains a somewhat high percentage of sulphur. The productions from 1912 to 1916 amounted to 16,403, 115,838, 268,242, 268,076, and 252,403 tons respectively.

The Baku production is about 80% of the total for Russia, and an 8-inch pipe-line with a nominal capacity of about 1,000,000 tons of kerosene a year connects the field with the port of Batum. In addition, the Trans-Caucasian Railway can, under normal conditions, handle 1,500,000 tons per annum.

Grosny produces about 16% of the Russian output, the outlet for which is the port of Novorossisk. The only means of transport is by rail, but a scheme has been put forward for the construction of pipe-lines from the district.

Oil deposits are being exploited at:

Ali Tepe, on the island of Cheleken, where there has been a steady decrease of output from 200,000 tons in 1912 to about 50,000 tons in 1916.

Maikop, in N.W. Caucasus, has been a disappointing field, being "pockety" in nature. Connected by pipe-lines with the field are refineries at Ekaterinoslav of total capacity probably in excess of present requirements. Productions from 1911 to 1917 were, respectively, 125,806, 146,774, 77,777, 62,903, 122,580, 33,871 and 32,258 tons.

Sviatoi, or *Holy Island*, which shows an increase of production from 22,000 tons in 1910 to over 120,000 tons in 1916.

Tchimion and *Sel Rokh*, in the Ferghana Valley, where in 1910 there was an output of 10,000 tons, which was increased to 34,000 tons in 1916.

Petroliferous territory has also been declared around Uchta (Archangel).

The production from the Russian fields was at one time the

largest in the world, but in 1916 it was only 15·62% of the world's output, as compared with that of the United States, viz. 64·5%.

Production for the years 1901–1920 has been as follows:

Year.	Metric tons	Year.	Metric tons.	Year.	Metric tons.
1901	12,195,508	1908	8,883,778	1915	9,792,580
1902	11,505,720	1909	9,424,350	1916	10,400,160
1903	10,798,751	1910	10,048,082	1917	8,362,903
1904	11,219,522	1911	9,454,813	1918	3,143,960
1905	7,851,467	1912	9,717,029	1919	3,642,571
1906	8,413,901	1913	8,976,336	1920	3,483,143
1907	8,835,819	1914	9,574,360		

The main outlet for supplies from Baku into the interior of Russia is via the Volga, but owing to the political disturbances this was closed for many months and the reconstruction of the industry was completely checked.

The Russian oil industry has suffered so seriously from the numerous internal upheavals of the past few years that its immediate future cannot be predicted with certainty.

If any considerable industrial revival took place, the available local production would probably not meet home requirements, with the result that little oil would be available for export.

Owing to the impossibility of disposing of its production, the industry was reduced almost to the verge of bankruptcy, the only means of paying wages being by receiving advances in local money on the security of stocks of oil, which accumulated to an enormous extent. Since April, 1920, when Baku came under Soviet control, much oil has been sent into the interior of Russia.

Spain

Deposits of asphalt are found in many parts of Spain in beds of various ages—Tertiary, Cretaceous and Jurassic—also small quantities of oil have been obtained when boring for salt near Santander in the north.

Turkey

Indications of oil have been found in sandy deposits, apparently of Miocene age, along the coast of the Sea of Marmora.

ASIA

In dealing with the continents of Asia and Africa, it must be remembered that there is little definite scientific knowledge available regarding the geology of vast territories, *e.g.* Arabia, China, Siberia, etc., and so the information given is necessarily incomplete.

Arabia

Bituminous deposits occur in the Eocene limestone near Wadi Gharandel, in Arabia Petræa, 40 miles south of Suez, and traces of oil have been met with in the Cretaceous (Nubian) sandstones of Wadi el Araba, 30 miles farther south. The indications of this latter district may be due to recent infiltration, as are also very probably those near the southern end of the Sinaitic Peninsula, and on Tiran Island at the mouth of the Gulf of Akabah Petroleum is also said to occur at many points in the interior of Yemen and at Benaid el Oar, near Koweit, on the eastern side of Arabia.

China

In China are two well-recognized oil-yielding provinces, Shensi and Szechuen, the most important district being in east central Szechuen, west of Tze-liu-ching, about 100 miles west of Chungking and south of Chintu. About 18 miles south of Tze-liu-ching there is also a heavy seepage, and gas is constantly emitted from crevices in the rocks. There are about 50 wells in operation in this province, the majority of which are in the Tze-liu-ching district. The production of the province amounts to about 30,000 barrels a year.

The production of oil in China has hitherto been entirely incidental to the salt industry, in which it is used as fuel. The wells have been stated to yield from 15 to 50% of oil, and from 50 to 85% of brine, the average proportion being about 33% oil and 66% brine. The crude oil so far produced burns with a clear flame and is a good illuminant.

The geological formations in China as they have been reported, follow:

Tertiary sandstone, yellow.
Limestone, grey.
Sandstone, red.

Oolite, orange-coloured, with petroleum at 600 feet.
Limestone, yellowish, with gas at 300 feet.
Marl, bluish grey, iridescent, white Permian chalk with brine 12 to 15% at 1,000–1,800 feet.
Schists, greenish, strong brine and flow of gas at 2,500–3,300 feet.

Imports of oil mainly consist of kerosene from the United States and the Dutch East Indies.

There is tank storage at both Hong Kong and Shanghai, principally for fuel oil for bunkering purposes.

Dutch East Indies

The islands of Borneo, Sumatra and Java, rank amongst the most important known sources of petroleum, and indications of oil in commercial quantities have also been found in the Celebes and Ceram islands.

The principal producing areas are (a) in Dutch-Borneo, the Koetei and Tarakan areas on the east coast, covering about 500 sq. miles; (b) in Sumatra, Langkat in the east, Perlak in Atchin Residency, and Palembang in the south; and (c) in Java, Semarang, Rembang and Soerabaya provinces in the north-east.

The oil-bearing strata are of Tertiary age, and generally associated with coal and lignite.

Borneo crude oil from Koetei has been found to contain an exceptionally high proportion of aromatic hydrocarbons, and is therefore valuable as a source of high explosive material, particularly toluol. Tarakan petroleum is a natural fuel oil, while Sumatra produces an oil very rich in petrol.

In the Koetei district of Dutch Borneo, the oil occurs mainly in Miocene sandstones, along anticlines with steeply-dipping sides, and is associated with heavy gas-pressure. The shallow sands in the Koetei fields yield heavy oil of 0·970 specific gravity, with paraffin. The lighter oils from deeper sources are poor in paraffin, and possess a specific gravity varying between 0·860 and 0·890.

The specific gravity of the Langkat oil of North Sumatra is given as from 0·771 to 0·857. In South Sumatra, the specific gravity of the oil from Meliamoen is from 0·765 to 0·775,

of that from Kampong Minjak, 0·792, and of that of the oil from Babat, 0·812 to 0·889.

In Java, the chief petroliferous horizon occurs at the junction of the Upper and Middle Miocene; the wells are quite shallow, varying in depth from 500 to 800 feet, and require pumping. The oil has a specific gravity of from 0·825 to 0·916, and is of asphaltic base, yet yields paraffin wax of high melting-point.

Production (in metric tons) for the period 1905–1920 has been as follows:

—	Dutch Borneo	Java	Sumatra	Ceram	Total.
1905 . . .	439,187	110,711	513,930	—	1,063,828
1906 . . .	387,455	111,378	602,501	—	1,101,334
1907 . .	489,151	142,983	713,841		1,345,975
1908 . .	511,049	137,013	738,588		1,386,650
1909 .	411,506	140,351	922,894	—	1,474,751
1910 . . .	633,172	143,003	719,540		1,495,715
1911 . .	814,705	172,438	683,525	—	1,670,668
1912 . . .	671,662	184,989	621,481	—	1,478,132
1913 . .	797,059	207,135	529,947	82	1,534,223
1914 . . .	866,718	226,590	466,423	487	1,560,218
1915 . . .	893,896	256,838	491,611	1,100	1,643,445
1916 . . .	957,395	249,442	520,080	3,263	1,730,180
1917 . . .	899,123	232,636	553,384	2,248	1,687,391
1918 . . .	999,174	225,879	478,068	3,554	1,706,675
1919 . . .	1,372,006	235,814	477,977	7,120	2,092,917
1920 . . .	1,455,128	311,677	496,351	20,980	2,284,136

Japan and Formosa

Japan.—The belt of oil-producing territory extends along the west side of North Japan, from the west coast of Sakhalin Island on the north, along the coast of the Sea of Japan, through the west side of the central mountain range of Hokkaido, thence stretching across the provinces of Mutsu, Ugo, Uzen, Echigo and Shinano, to the Pacific coast of Totomi in the south. The principal producing districts are Akita in the province of Ugo and Niigata in the province of Echigo. The producing sandstones are of Tertiary age, interstratified with beds of slate or shale, and most of the production is obtained from shallow wells less than 700 feet in depth.

Drilling first took place in Echigo in 1890, when the Nippon Oil Co. successfully brought in a well in the Amaze field, and the development of other districts rapidly followed. The

first gusher was brought in at Kurokawa, in the Akita district, in 1914, with an initial production of 10,000 barrels a day. Several others have since been obtained, and in 1916 a new field was proved along an anticline in the Urayama district, parallel with a similar fold in the Kurokawa field. The output has, however, gradually declined, that of 1918 being 101,728 tons less than that of 1915.

The total production for the years 1901–1920 has been as follows:

Year.	Tons.	Year.	Tons.	Year.	Tons.
1901	159,527	1908	204,549	1915	442,793
1902	172,023	1909	268,913	1916	425,415
1903	172,853	1910	240,718	1917	411,768
1904	202,782	1911	248,231	1918	342,814
1905	210,400	1912	236,659	1919	285,000
1906	243,682	1913	274,844	1920	280,000
1907	281,880	1914	388,810		

Formosa.- Indications of petroleum, which have been discovered in Formosa in about 300 localities, occur in 26 oil belts extending for at least 400 miles along the west coast. The Byoritsu and Tabanti fields in the north have already been proved, and the Nairo and Kosempo fields in Ako district, the Senschuiryo field in Tainancho, and the Rokiyukei field in Kagicho are all being exploited.

Distillation of an average sample of the oil gave the following results:

Specific gravity of crude oil	0·8284
Motor spirit (under 150° C.)	10%
Kerosene (150°–300° C.)	80%
Heavy oil (paraffin and residue)	10%

The production since 1906 has been as follows:

Year.	Tons.	Year.	Tons.
1906	713	1913	2,586
1907	1,000	1914	2,387
1908	1,186	1915	2,702
1909	919	1916	2,753
1910	520	1917	2,791
1911	234	1918	1,926
1912	493		

Persia

The oil-fields of Persia extend in a south-easterly direction along the western and southern sides of the Persian plateau adjoining Mesopotamia, the Persian Gulf and Gulf of Oman,

cross the Turco-Persian frontier between the Diyaleh (or Sirvan) River and Mendeli, and enter the Persian province of Kermanshah. Thence they run south-east through the provinces of Luristan, Arabistan, and the Bakhtiari country forming the northern area, and the Behbehan Fars and Laristan forming the southern area.

Recent investigations by H. G. Busk and H. T. Mayo have thrown considerable light on the previously obscure geology of certain of the petroliferous areas in Persia. Mr. H. T. Mayo has kindly furnished particulars from which the following account of the geology of the petroliferous areas in S.W. Persia and the Persian Gulf region has been prepared:

The petroliferous areas of Persia and the Persian Gulf may be considered under three heads, viz.:

1. *The Bakhtiari Region*, in which the main oil field is situated.

2. *The Ahwaz-Pusht-i-Kuh Region*, extending to the Mesopotamian frontier.

3. *Qishm Island* and the *Persian Gulf Region*.

The main stratigraphical divisions throughout these three regions are as follow:

1. *The Asmari Series* (Cretaceous to Oligocene): thickness, 2,000 feet, principally massive limestones, succeeded by—

2. *The Fars Series* (Miocene) more than 7,000 feet thick, divided into three groups: the Lower Fars, formed of some 3,500 feet of massive gypsum, shales, clays and intercalated beds of limestone; the Middle Fars, consisting of 1,000 feet of clays, shales, intercalated gypsum, limestone and sandstone; and the Upper Fars, forming 2,700 feet of clays, shales and intercalated sandstones. The Fars series is overlaid by—

3. The *Bakhtiari Series* (Pliocene), of which the lower group consists of 13,000 feet or more of clays, sandstone and conglomerate, and the upper of 2,000 feet of massive conglomerate.

The principal oil-bearing zone is the Lower Fars group, in which the oil occurs in shelly vesicular limestones; it also occurs in the Middle Fars group at Dareh-i-Qil, 30 miles N.E. of Maidan-i-Naftun, Marmatain, 10 miles E. of Ram Hormuz, and White Oil Springs, 20 miles S.E. of Maidan-i-

Naftun. Of these localities, Marmatain and White Oil Springs have been tested by the drill, but without very satisfactory results. In the former case the underlying gypsiferous group, and not the Middle Fars, was tested, whilst at White Oil Springs a small show of naturally-refined water-clear oil similar to that seeping at the surface was struck. Residual seepages, from the gypsiferous group, also occur in the upper members of the Asmari series; oil is doubtfully indigenous in the latter in some cases.

(1) *Bakhtiari Region.*—The strata of the Fars series were deposited under quiescent conditions in a broad geo-synclinal. Throughout the succeeding Bakhtiari period, there was constant but gradual earth-movement, resulting in the formation of a series of synclines and anticlines, the axes of which have a N.W.-S.E. orientation. The Upper Bakhtiari conglomerates, 2,000 feet in thickness, have been spread over the finer-grained sediments of the Lower group, often resting unconformably upon the upturned edges of the latter. The structure has also been influenced by post-Pliocene movements, continuing down to the present day, and the whole district has been much affected by faulting and thrust planes.

Within this area is situated the Maidan-i-Naftun oil-field. This field is characterized by minor folding, but lies in the "open" portion of the Maidan-i-Naftun anticline, which to the N.W. is compressed into omega form. The main producing oil zone is met with at from 1,100 to 1,400 feet.

(2) *The Ahwaz-Pusht-i-Kuh Region* presents similar tectonic features to the above, but disturbance has been less intense. The Ahwaz Range is a low and irregular anticlinal line of hills rising out of the Mesopotamian alluvial plain, and striking W.N.W. and E.S.E., through Ahwaz, it is the farthest recognizable outlying fold of the Iranian mountain chain. The fold has been traced for a distance of over 100 miles N.W. and S.E. of Ahwaz. A test well was drilled in 1913, E. of the Karun River, in the neighbourhood of Ahwaz, on the N.E. flank of an asymmetrical but well-developed dome. An approximate correlation with the known stratigraphic sequence was adopted, based on general lithological characters. The lower two or three hundred feet of beds exposed were classed provisionally

as a lower sub-group of the Upper Fars. Later they were recognized as belonging to the Middle Fars passage group, a correlation which has recently been confirmed by the survey of the more remote north-westerly extension of the fold.

(3) *Qishm Island and the Persian Gulf Region.*—Qishm is the largest island in the Persian Gulf, near its entrance and opposite the coast between Lingah and Bunder Abbas; it is more than 60 miles long, and has an average breadth of from 8 to 10 miles. The rocks exposed are those of the Hormuz series, the upper group of the Fars series, and the Pliocene Tersai series.

The Upper Fars beds, a calcareous phase, occupy the greater part of the ground, and are disposed in a series of gentle domes, approximately symmetrical quaquaversals along an axis running through the length of the island

The Hormuz series constitutes a roughly circular inlier with steep or vertical uppermost beds at the margin. Two distinct rock groups are included, a basal Namakdan group with massive rock-salt, laminated shales and dolomitic limestone, and an upper pyroclastic Pusht Tumba group of volcanic agglomerates and gypsiferous tuffs. Pilgrim, who made the first geological examination of Qishm Island in 1904, assigned to the Hormuz series a post-Cretaceous, pre-Nummulite age.

There has since been a certain amount of controversy concerning both the stratigraphy of Qishm Island and the nature of the tectonic processes responsible for the Hormuz inlier and the Upper Fars domes. The key to the stratigraphy has been found in a study of the adjoining Persian mainland. By this means the pre-Oligocene age, at least, of the Hormuz series has been established.

A test well on the apex of the Salukh dome, adjoining the Namakdan Hormuz inlier at the N.E. end of the island, was started in 1915. The advantages of this dome are: (1) that it provides a lower initial horizon in the Upper Fars group than any of the other five domes of the island; and (2) that it possesses the only oil-seepage, the latter occurring near the apex. After passing through the Upper Fars beds, the drill entered first the normal middle, and then the normal gypsiferous

Lower Fars group, as developed on the adjoining mainland. Its depth in January, 1919, was a little over 2,000 feet. Several light shows of gas and oil have recently been encountered.

The record of the well has thus confirmed the solution of the stratigraphy of the island arrived at from a study of the mainland, namely, concealed progressive overlap, the Middle Fars group overlapping the Lower, and the Upper the Middle, against the older Hormuz series.

Brief reference only can be made here to the geology of the Persian mainland in the Gulf region.

A general stratigraphic correlation has been effected from the Indian frontier into Central S.W. Persia.

A test well, which is being drilled on the Chandragup dome, 100 miles W. of Karachi, is designed to test strata which are approximately the stratigraphic equivalent of the petroliferous Lower Fars group of Persia; incidently, both are approximately to be correlated with the petroliferous Pegu series of Burma, and with the oil-series of Assam.

Lateral variation along the general line of strike has been traced in the Fars groups by Lister James, between the Bakhtiari country and the neighbourhood of Bushire. The coastal facies is reduced in thickness and is of deeper-water type than that of the Bakhtiari country.

Of other areas in the Persian Gulf region, known or believed to be more or less favourably circumstanced as regards oil prospects, mention may be made of Bahrein Island. This island lies in an arm of the Persian Gulf, on the Arabian side, W. of the peninsula of Qatar. The only rocks exposed are compact Eocene limestones with flints, and saliferous marls. The structure is that of a gently elongated dome. Near the apex is an important asphalt deposit, the asphalt emanating from the limestone.

Oil is conveyed from the Maidan-i-Naftun oil-field about 145 miles by two pipe-lines to the refinery situated on the island of Abadan. The original capacity of the pipe-lines is being very considerably increased by additional pumping

stations, and in order to deal with the increased output, extensions to the refinery at Abadan are being carried out, while a refinery is also being erected at Swansea, England.

The output has increased from less than 100,000 tons in 1912 to more than 1,000,000 tons in 1918.

The oil is of high quality, containing a large percentage of benzine, kerosene and lubricating oils of good quality, fuel oil of unusually high calorific value, and a valuable percentage of paraffin wax.

A distillation test gave the following result :

Specific gravity	0·840
Initial boiling point	48° C.
Distillation below 100° C	11·0%
Distillation between 100° and 150° C	12·3%
Distillation between 150° and 280° C	29·6%
Residue	45·6%
Loss	1·5%

Philippine Islands

Petroleum occurs as a very light paraffin-base oil, at various points in the Philippine Islands, notably in the Bondoc Peninsula, at Toledo and Algeria in the Island of Cebu, and at Tayabas and Luzon. Indications are also reported to occur on the islands of Palawan, Leyte and Mindanao, whilst the islands of Panay, Guimaras, Negros and Bohol appear worthy of further investigations.

Bondoc Peninsula.—American interests recently sent out a geological expedition, and, as a result of favourable reports of petroleum indications, are actively sinking test wells.

Cebu Island.—In 1914 a company was reported as formed for exploiting the petroliferous areas of Toledo.

Sakhalin (Russian)

For a distance of nearly 200 miles and in a belt 6 to 12 miles wide along the Pacific coast of the northern half of Sakhalin, oil indications have been reported in the Tertiary sandstones. Asphalt is found in all stages of density, from the consistency of tar up to a hard, smooth-surfaced mass resembling an asphalt floor. The lake near Oha Creek,

over 1,000 feet long, 400 feet wide, and from 2 to 6 feet deep, is estimated to contain more than 25,000 tons of a tough asphalt-like substance comparatively free from foreign matter. Little development work has so far been done.

SYRIA

Large deposits of asphalt are reported to exist in the neighbourhood of Latakia, near the villages of Kferie, Cassab, Ghoman, Chmeisse, Khorbe and Sonlas; also at Hasbeya, on the Upper Jordan, Sahmur and Ain-et-Tineh, on the Nahr Latini, and another Ain-et-Tineh near Magluda.

In Northern Syria a petroleum spring has been reported to the south-east of Alexandretta.

See also "Palestine," p. 25.

TIMOR (PORTUGUESE)

Indications of oil have been found in the eastern half of the island of Timor, belonging to Portugal, where limestone is found coated with asphalt and ozokerite, yielding 24% of crude oil, and pools of black viscous oil are found on the surface.

There are many natural difficulties to be overcome, but it is thought that oil may exist in quantity at a depth of from 1,200 to 1,500 feet in a Triassic formation, and investigations are to be made with a view to a practical test later, if the conditions are favourable. Unfortunately, the geological formations are much disturbed by earthquake action. Many prospectors of various nationalities have visited Timor, but have abandoned their concessions.

One sample of oil from Timor, of specific gravity 0·840, gave a flash-point (Abel close test) of 112°. Another sample yielded 64·6% of kerosene and about 30% of intermediate lubricating oils.

AFRICA

ALGERIA

The oil-bearing region of Algeria, of which Messila is the centre, stretches north-east from Nadour to Medjila. There is a large and well-defined anticline consisting of Cartennian

marls with occasional bands of sandstone. The oil, of which various beds have been proved, occurs in the Miocene strata.

Petroleum has been produced in small quantities near Orān, where wells sunk to a depth of 1,400 feet have given small but persistent yields, which have enabled a small refinery to be worked at intervals.

Producing wells have been sunk in the Messila and Medjila areas, and also at Nehma, near Relizane, in the Tliouanet district. The oil, which is of good quality and rich in kerosene and intermediate oils, has a dark, reddish-brown colour, very little fluorescence, and a pleasant benzine odour, with an absence of sulphur compounds. A typical analysis is as follows:

Specific gravity at 60° F.	0·820
Flash point	50° F
Sulphur	0·15%
Benzine	nil to 7·3%
Kerosene	60·3 to 67·6%
Intermediate and heavy oils	29·2%

French Cameroon

Black bituminous shales, which are easily ignited with slight heating, occur in the Munro district of French Cameroon, near Duala, and seepages of petroleum have been noticed.

French Congo

Indications of petroleum are reported from the Fernand Bay district and from the Nguni and Ogowai rivers.

Madagascar

The existence of oil deposits in the Betsiriry and Sakalava valleys, in the west of Madagascar, has been proved, but no discovery of commercial importance has yet been made.

Boring operations have been effected in both localities. In 1916, oil was stated to have been found in two wells at Sakalava, and in 1917 oil and gas shows were met with in another well at 450 feet.

MOROCCO

The belt of Tertiary rock in which petroleum is found in Algeria extends across Morocco to the Atlantic coast, and there is, therefore, a probability that similar indications of oil will be found in the latter country. Traces do, in fact, exist in the Fez district at Ulad Aissa, Sherada and Ain Feriba, and heavy oil seepages are also reported in the north-east near the Arab villages of Kohlott, Khairott and Ouled Slama, those at the last-named place being the most important. These oils are of a heavy and bituminous nature, almost black, and ooze out of the ground during wet weather in the form of an emulsion.

Petroleum has recently been discovered at Djebel Tolfat, near Petit Jean in the French zone, and twelve new shafts were to be sunk in 1920.

It has been reported that oil has been discovered near Melilla in the Spanish zone, and that the field is to be exploited by a strong Spanish company.

PORTUGUESE WEST AFRICA (ANGOLA)

Portuguese official reports as far back as 1844 refer to the existence in Angola of extensive deposits of petroleum, most of which are stated to be near the coast or navigable rivers. In 1915 boring was in progress a few miles from the mouth of the River Dande, to the north of Loanda, but no oil has yet been located. Indications of petroleum occur also at Libollo. It is understood that active development under American auspices is now proceeding.

TUNIS

Surface indications and the results of a preliminary test point to the existence of a group of petroliferous rocks in Tunis, but the complex geological structure of the country renders unlikely the production of oil on a commercial scale in the near future.

The oil indications appear to be situated chiefly within a belt trending south-west from the Mediterranean coast at Bizerta and Tunis to near the Algerian frontier.

NORTH AMERICA

Costa Rica

It is understood that concessions for the development of prospective oil-fields were granted a few years ago to British and American interests over the northern and southern portions of the Republic of Costa Rica respectively, but apparently no definitely successful results have yet been achieved.

Cuba

The petroliferous area of Cuba lies between Cape San Antonio, at the western extremity, and a line drawn north and south at about 80° west longitude, east of Santa Clara; it covers the provinces of Pinar del Rio, Havana, Matanzas, Cardenas and Santa Clara, in all of which asphaltic outcrops and petroleum seepages are found. The oil belt is about 700 miles long by 25 miles broad, and runs parallel to the main mountain range. Along the north coast there are several large and deep deposits of high-grade asphalt, but efforts which have been made to find petroleum along the north coast, west of Havana, have not so far been successful.

Numerous wells have been sunk in different parts of the island, but no considerable production has been obtained. Owing to the scarcity of coal, however, the use of imported fuel oil is making considerable headway. Most of the large sugar mills have already installed oil-burning equipment, and the railway engines are also being modified to use oil.

Guatemala

Surface indications point to the possibility of oil being obtainable in Guatemala in the departments of San Marcos and Huehuetenango, and also in the northern and north-eastern parts of the departments of Quiche, Alta Vera, Paz and Izabal.

Honduras

Honduras is reported to afford numerous and extensive indications of petroleum on the Caribbean coast-line, the most noticeable being at Guare, 66 miles south of Puerto Cortez.

Mexico

Miguel Bustamante, the Mexican geologist, divides the Republic of Mexico into three petroliferous zones: (1) the *Gulf zone*; (2) the *Central zone*, and (3) the *Pacific zone* (including Lower California).

The Eastern Sierra Madre separates (1) from (2), and the Western Sierra Madre separates (2) from (3). The principal mountain chains run north-south, but the zones between are subdivided by secondary chains trending approximately east-west. All three zones are characterized by Cretaceous, Tertiary and Quaternary sedimentary, and by Tertiary eruptive rocks. In Mexico the eruptive rocks have had considerable influence on the accumulation of both oil and coal. The principal oil fields have hitherto been found in the Gulf zone, especially in the State of Vera Cruz, in Cretaceous and Tertiary formations. In some cases the oil is primary or is indigenous in the former, and in others, secondary, or has migrated from Middle and Lower Cretaceous and Jurassic. Bustamante thinks it very probable that deposits of coal and oil may be met with in economic quantities in the Jurassic and Carboniferous formations, but these formations are very rare, or at any rate of small extension superficially in Mexico.

According to L. G. Huntley, petroleum in Mexico occurs in the upper part of the Tamasopa limestone, which is somewhat porous, usually fractured and of Cretaceous age, as well as in the San Felipe beds of limestone and blue and brown shales, from 200 to 700 feet thick, which overlie it. Above the San Felipe series occur the Mendez marls and shales, from 2,000 to 3,000 feet thick. These beds are also petroliferous, but petroleum is not usually found in them in any quantity. Above these are sandy limes and sandstone, and limy and sandy clays of Oligocene age. The Mendez marls and San Felipe shales are probably of Eocene age. Huntley believes the marine marls, known as Mendez marls, to be the origin of the oil found in the lower formation, although this opinion is not shared by Degolyer, Bustamante and other geologists. Oil is found where there is a favourable anticlinal or dome structure, with pronounced fracturing of the formation; these fractures

(frequently faults of relatively small throw) are usually accompanied by basaltic intrusions and seepages of asphalt (*chapopoteras*) and gas. Intersections of strong fractures are frequently accompanied and marked at the surface by conical basalt peaks, which usually represent the " mushrooming " of an igneous rock intrusion.

The Gulf zone is situated in the coastal plain, and extends from the Tecolutla River in the district of Papantla in the south to the Tamesi River in the north: developments are anticipated, however, both north and south of these limits.

The principal fields within the area are as follow:

Ebano, 30 miles west of Tampico port, on the Tampico railway. It has a production of about 6,000 barrels a day of low-grade oil, most of which is sold to the National Railways as fuel oil.

Panuco, 25 miles W.S.W. of Tampico on the Panuco River, where the wells at present drilled are estimated to have a potential production of at least 250,000 barrels daily. Several large gushers have been drilled and extensions of the field proved. The oil is valuable chiefly as fuel for the manufacture of asphalt, and is mostly exported to the United States. There is an 8 inch pipe line to Tampico, via Topila

Topila, about 17 miles W.S.W. of Tampico, near the Panuco River, has a production of about 2,000 barrels a day. The 8-inch pipe-line from Panuco to Tampico passes through the field.

San Pedro, 75 miles W.S.W. of Tampico, produces a high-grade oil, but it is understood that the field is closed down for the present.

Juan Casiano, 60 miles south of Tampico. The rapid developments in this and the Potrero del Llano field in 1910 were regarded as the first conclusive indications of the existence of large supplies of oil in Mexico.

Los Naranjos, 3 miles S.W. of Juan Casiano.

Additional fields adjoining Los Naranjos have been proved by the bringing in of very large wells at Chinampa, Tepetate and Amatlan recently.

Potrero-Alazan.—An extension of the field was proved in 1912 by the bringing in of a well at Alazan with an initial yield of 15,000 barrels a day.

El Alamo, 23 miles S.W. of Tuxpam. An 8-inch line connects the field with Tuxpam Bar, whence the oil is shipped. The production in 1917 was about 7·4 % of the total Mexican output for that year.

Furbero, 45 miles S.W. of Tuxpam. It had an output in 1917 of 34,689 barrels.

According to E. Degolyer, the general structure of the Furbero oil-field is an eastward-dipping monocline, the beds of which are gently folded. The folding took place in Oligocene and post-Oligocene time, and the general strike is N.W.–S.E. A laccolite, or extremely thick sill of gabbro or dolerite, has given rise to the Furbero pool. The sedimentary rocks (shales) had already been folded into an anticline when the intrusion occurred, which followed closely the bedding planes, and thickened near the crest of the anticline. Above the apex of the intrusion, the metamorphosed shales continue in the form of a pipe or chimney to the surface.[1] Degolyer also states that the determining factor in the accumulation of oil has been the providing of pore space for a reservoir by the metamorphism accompanying the igneous intrusion of the under- and overlying-shale, which was previously impervious.

In the Southern region, or southern portion of the Central zone, which comprises the *Isthmus of Tehuantepec* and the *Tabasco district*, the oil occurs in rock of Pliocene and Pleistocene ages, the formation usually being a true quartz sand. Owing to the disturbed political conditions all work was stopped early in 1917, in which year the production was only 23,556 barrels. There are fields at *Ixhuatlan*, *Tecuanapa Soledad*, *San Cristobal*, *La Reforma* and *Pichicalco*, and promising indications are said to have been found at *Campeche*, State of Campeche. Prospecting is also being carried out in Yucatan.

[1] The cross-sections of the anticline with laccolite, given by Degolyer, seem to bear a striking resemblance to the well-known saddle-reefs of Bendigo, Victoria, Australia, the essential difference being that the auriferous quartz of the latter is represented by gabbro or dolerite in the former. If the formation at Furbero is really a saddle one, there is a possibility that other laccolites and oil accumulations occur below those already proved by borings.

In the Pacific zone, petroleum deposits occur in Lower California, where indications have been found at *San Miguel*, 30 miles north of Enseñada, and at *Tunta Bonda*, a few miles to the south. Oil is also reported to have been struck on an island near the port of *Altata*, Sinaloa, and there are said to be extensive deposits on the island of *Angel de la Guarda*, in the Gulf of California.

Chihuahua.—A deposit of a paraffin base oil has been found in Chihuahua, not far from the United States boundary.

Submarine Deposits.—A report recently submitted to the Mexican Government points to the existence of large submarine deposits off the coast of Sotaventa

Generally speaking, Mexican petroleum is very heavy in the northern fields, but in the south lighter varieties are found.

The average of 20 samples from the former gave a specific gravity of 0·927, whilst those of oils from the Isthmus of Tehuantepec varied from 0·792 to 0·881.

The calorific value of Mexican fuel oil of 0·950 specific gravity (at 60° F.) is about 18,900 B T.U. per lb.

According to a United States Government report, Mexican oil is either of an asphaltic, or of mixed asphaltic and paraffin base, and, due to the large amount of asphalt present, it has hitherto been regarded as less suitable than United States oil for the manufacture of high-grade lubricants. The yield of petrol varies from about 12 to 15% in the lighter grades of crude oil to about 3·5% in the heavier grades, the amount of kerosene varying from 7 to 4%.

Drilling developments in Mexico have been so rapid that, at present, although there is a potential production of about 1,500,000 barrels of oil a day, owing to shortage of pipe-lines and loading capacity, the actual production is less

than one-fifth of this. The area exploited in obtaining this result is under 6,000,000 acres out of a total of 380,000,000 acres of possibly productive land. Recently, some anxiety has been caused by the entry of salt water into some of the Mexican fields, those of Potrero, Alazan and Tepetate being more particularly affected.

The total Mexican production for the years 1901–1920 has been as follows:

Year.	Metric tons	Year	Metric tons	Year.	Metric tons.
1901 . .	1,478	1908 . .	561,843	1915 . .	4,701,501
1902 . .	5,743	1909 . .	387,643	1916 . .	5,792,245
1903 . .	10,768	1910 . .	519,154	1917 . .	7,898,967
1904 . .	17,946	1911 . .	1,793,257	1918 . .	9,118,332
1905 . .	35,893	1912 . .	2,365,405	1919 . .	12,439,000
1906 . .	71,786	1913 . .	3,670,899	1920 . .	22,800,000
1907 . .	143,571	1914 . .	3,747,915		

On all oils exported a duty is payable at the rate of 10% of the value of such oils, the valuation being based on New York market prices and higher rates being proposed.

Uncertain political conditions in Mexico have greatly interfered with the development of the petroleum industry, and the producing companies have been much alarmed by the introduction of legislation declaring that the subsoil and its contents are the property of the State. This measure has, however, been modified so as to apply only to lands at present in private ownership, respecting which, contracts of exploration or exploitation of the subsoil were not taken up before May 1, 1917, and all lands in respect of which the owner of the surface had not demonstrated by actual operations before that date his intention to possess the substances of the subsoil.

Article 27 of the Mexican Constitution of 1917, under which the Mexican Government based its original claim, reads as follows:

"Only Mexicans by birth or naturalization, and Mexican companies, have the right to acquire ownership in lands, waters, and their appurtenances, or to obtain concessions to develop mines, waters or mineral fuels in the Republic of Mexico.

The nation may grant the same right to foreigners, provided they agree before the Department of Foreign Affairs to be considered Mexicans in respect to such property, and accordingly not to invoke the protection of their Governments in respect of same, under penalty, in case of breach, of forfeiture to the nation of the property so acquired.

"Within a zone of 100 km. from the frontiers, and of 50 km. from the sea coast, no foreigner shall under any conditions acquire direct ownership of lands and waters."

San Domingo

Indications of petroleum in the form of seepages are found near Azua, in the province of the same name, on the south coast, about 60 miles west of the capital, and also near San Cristobal. An attempt made to develop the Azua area proved unsuccessful owing to difficulties with sea water, but it is understood that American companies are about to make further tests by deep drilling.

Panama

Prospective oil-fields have been reported to exist in the province of Chiriqui.

Early in 1917 the National Assembly at Panama authorized the Executive to make concessions of unoccupied territory to persons exploring for oil or gas for terms not to exceed three years, and to make contracts for the working of oil lands for periods of twenty years, subject to renewal or extension for a second period of equal length.

American companies are understood to have been prospecting for oil in various regions of Panama, especially at Bocas del Toro, in the Colon district. Good indications of oil in payable quantities are reported.

In August, 1918, it was stated that reinforced concrete oil-tanks were being erected on the Isthmus, the first of these, with a capacity of 55,000 barrels, then being in course of construction at Mount Hope in the Canal Zone.

UNITED STATES.

The oil-fields of the United States are widely scattered throughout the country, the area actually producing covering some 1,500 sq. miles, or less than one-twentieth of one per cent of the area of the country. In addition, about ten times as much is held under lease or in fee in the hope that it may prove oil-bearing, a part of this consisting of the undrilled portions of tracts that are already producing.

The fields are generally divided as follow: (1) Appalachian; (2) Lima-Indiana; (3) Illinois; (4) Mid-continent; (5) Gulf; (6) Rocky Mountain; (7) California; (8) Miscellaneous. The main oil-producing areas may also be grouped in four principal regions: (*a*) the eastern, including the Appalachian, Lima and Illinois fields; (*b*) the south-central, including the Mid-continent and the central Texas Gulf fields; (*c*) the Rocky Mountain; and (*d*) the western or Californian region. Each of these regions is growing gradually as new fields are from time to time discovered in the surrounding territory.

As the fields extend, the geographic boundaries become in many cases less distinct, and the separation is gradually being based more and more on fundamental differences in the type of oil produced and its adaptability to refining needs. Thus, the oils of the Appalachian field are in the main of paraffin base, free from asphalt and objectionable sulphur, and yielding by ordinary refining methods high percentages of gasoline and kerosene, the products in greatest demand. Contrasted with them is the petroleum of the Lima-Indiana field, which contains some asphalt, though consisting chiefly of paraffin hydrocarbons, and is contaminated with sulphur compounds, which necessitate special treatment for their elimination. Illinois oils contain various proportions of both asphalt and paraffin, and differ considerably as to specific gravity and distillation products. Sulphur is generally present, but rarely in such form as to necessitate special treatment for its removal. Mid-continent oils vary in composition within wide limits, ranging from asphaltic oils, poor in gasoline and illuminants, to oils in which the asphalt content is negligible and which yield on distillation high percentages of the lighter

products. Sulphur is present in various quantities in the lower-grade oils, in certain of which—Healdton, for example—it exists in a form requiring special treatment for its elimination. Oils from the Gulf field are characterized by relatively high percentages of asphalt and low percentages of the lighter gravity distillation products. Considerable sulphur is present, much of which, however, is in the form of sulphuretted hydrogen and is easily removed by steam before refining or utilizing the oil as fuel. Oils from Wyoming and Colorado are in the main of paraffin base, suitable for refining by ordinary methods. Heavy asphaltic oils of fuel grade are also obtained in certain of the Wyoming fields. The California oils are generally characterized by much asphalt and little or no paraffin, and by varying proportions of sulphur. The chief products are fuel oils, lamp oils, lubricants and asphalt, though low percentages of naphthas may be derived from certain of the lighter oils, notably those of the Santa Maria, Sespe and Santa Paula fields, in the southern part of the state.

The oil industry in the United States is generally regarded as having had its beginnings in Pennsylvania in 1859, when E. L. Drake found petroleum at Titusville by boring to a depth of about 70 feet. Small quantities of oil had, however, been produced at various points in Pennsylvania, West Virginia, Kentucky and elsewhere for many years previously.

Although oil and gas had been known and used for centuries, particularly in Europe, there was practically no development of the industry until the fields of the United States began to be actively exploited. The world's production of petroleum up to 1859 was a few thousand barrels. Two years later, in 1861, the United States alone yielded over 2,000,000 barrels,[1] or more than 100 times as much as all the rest of the world for that year. In recent years the share of this country in the world's production has averaged 66%, and the total yield has been about 4,500,000,000 barrels against 2,500,000,000 for the rest of the world. In some quarters there is a belief, based on scientific considerations, that the proportion of the world's production yielded by the United States will soon begin to show a decline.

[1] 1 barrel = 35 Imp. gal. = 42 Amer. gal.

Up to the present, about 4,598,000,000 barrels of crude oil have been extracted, while a recent estimate of that remaining underground in the known fields is 6,740,000,000 barrels. Against the prophecies of exhaustion have to be set the repeated discovery of new fields, such as Cushing, Ranger and Burkburnett.

The general development of the oil-fields of the country has proceeded westward, but in 1876 the eastern producing states (Pennsylvania, New York, Ohio, West Virginia) received a noteworthy accession by the entry of California, the westernmost and now one of the principal producing states, which thus preceded the central states Kentucky, Illinois, Kansas, Texas, Oklahoma and Louisiana. Pennsylvania, New York, Ohio and West Virginia, together have produced about 1,500,000,000 barrels; California about 1,000,000,000; and Oklahoma about 600,000,000. Oklahoma and California are the only states which have in any single year produced more than 100,000,000 barrels. Prior to 1906 Oklahoma produced annually less than 1% of the total for the country, whereas now it is yielding 25 to 30%.

The oil-bearing formations of the United States range in age from Ordovician to Late Tertiary, but the greater part of the production comes from the Carboniferous, Cretaceous and Tertiary. A good deal of oil is found in the Devonian formation in Kentucky and other states, and large quantities in the Ordovician, particularly in the "Trenton rock" of the Lima-Indiana field. The Appalachian and Mid-continent oils are mainly in Carboniferous sandstones, and the Gulf Coast and California oils in Cretaceous and Tertiary sands.

Geologically, the oil pools of the United States are found in a wide variety of structures, but generally it may be said that the oil-fields occur in major or minor anticlines, occupying the basins formed by the mountain ranges of older formations. Many of the pools, particularly where the rocks are almost perfectly flat, as they are in parts of Pennsylvania and adjoining states, do not show any close relation to structure; but, on the other hand, the great majority of the pools throughout the country do show an obvious structural relationship, and the determination of structure has come to play a very

important part in the search for new pools. Some large groups of pools are located on major uplifts in the sedimentary basins, such as the Lasalle anticline in Illinois and the broad anticline in north-central Texas, upon which the Ranger fields have recently been found. The heights of the minor anticlines vary from the almost imperceptible undulations of portions of the Appalachian field to the sharp domes and anticlines of the Gulf and Pacific coasts, which are commonly many hundreds of feet in height and have limbs sloping as much as 30° to 50°.

The main characteristics of the regions are shown in the table on page 78.

The following table gives the production figures for the years 1901–1920:

Year.	Barrels.	Year.	Barrels.	Year.	Barrels.
1901	69,389,194	1908	178,527,355	1915	281,104,104
1902	88,766,916	1909	183,170,874	1916	300,767,158
1903	100,461,337	1910	209,557,248	1917	335,315,601
1904	117,080,960	1911	220,449,391	1918	355,927,716
1905	134,717,580	1912	222,935,044	1919	377,719,000
1906	126,493,936	1913	248,446,230	1920	443,402,000
1907	166,095,335	1914	265,762,535		

The above totals are divided amongst the various fields as shown in the table on page 79.

Full details of the production by states and fields are determined and published by the U.S. Geological Survey in a series of annual reports entitled *Mineral Resources of the United States.*

Imports.—Despite the fact that the United States is the world's principal producer and distributor of petroleum and petroleum products, her import trade in these commodities is steadily increasing. This is especially true with regard to grades of oil desired for use as fuel, including both crude petroleum and "topped crude," available from Mexico.

The following table shows the imports, in barrels, of crude and refined petroleum for the years 1917–1920:

—	1917	1918	1919	1920.
Crude	30,126,677	37,735,642	52,821,567	106,175,289
Refined	1,400,875	1,207,148	1,339,649	2,618,549
Total	31,527,552	38,942,770	54,161,216	108,793,838

Characteristics of the Oil Regions of the United States

Region.	States included.	Age of oil horizons.	Oil-bearing strata.	Structure.	Nature of oil.
Appalachian	New York, Pennsylvania, W. Virginia, S E Ohio, Kentucky, Tennessee and N. Alabama.	Carboniferous (chief) and Devonian.	Sandstone and conglomerates.	Anticlinal and other favourable structures.	Paraffin base, no asphalt or sulphur.
California	California.	Tertiary (Miocene) (chief).	Sandstone, sandy conglomerates, clays, etc.	Sharp domes and anticlinal.	Asphalt high, little or no paraffin, variable sulphur.
Lima-Indiana	Indiana and N W Ohio.	Ordovician (chief), Silurian and Carboniferous.	Porous dolomite (Ordovician), limestone (Devonian and Carboniferous).		Paraffin hydrocarbons with some asphalt and sulphur.
Rocky Mountains	Colorado, Wyoming, Montana, Utah and New Mexico.	Carboniferous (chief) and Cretaceous.	Sandstone, limestone and shale (rare).		Asphaltic base.
Illinois	Illinois.	Carboniferous.	Sandstone.	Anticlinal.	Asphalt, with some paraffin and sulphur.
Mid-continent	Kansas, Oklahoma, N. and Central Texas, N. Louisiana.	Tertiary, Cretaceous, Upper Carboniferous and Permian.	Sandstone (Upper Carboniferous and Permian).	Anticlinal.	Asphalt to paraffin base.
Gulf	Texas and Louisiana (portion of Gulf Coastal Plain).	Cretaceous to Quaternary.	Porous dolomite, limestone or sandstone.	Dome.	Asphalt high.

Production of Oil by Fields in the United States

(Expressed in barrels of 35 Imp gal.)

Year.	Appalachian.	California	Lima-Indiana	Rocky Mountains	Illinois.	Mid-continent.	Gulf.	Other.	United States Total.
Prior to 1908	947,150,206	201,965,825	386,960,115	8,960,070	28,866,683	94,651,699	138,023,394	21,471 [1]	1,806,608,463
1908	24,945,517	44,854,737	10,032,305	397,428	33,686,238	48,823,747	15,772,137	15,246 [1]	178,527,355
1909	26,535,844	55,471,001	8,211,443	330,917	30,898,333	50,833,740	10,883,240	5,750 [1]	183,170,874
1910	26,892,579	73,010,560	7,253,861	355,224	33,143,362	59,217,582	9,680,465	3,615 [1]	209,557,248
1911	23,740,832	81,134,391	6,231,164	413,021	31,317,038	66,595,477	10,999,873	7,995 [1]	220,449,391
1912	26,338,516	87,272,593	4,925,906	1,778,358	28,601,308	65,473,323	8,545,040	—	222,935,044
1913	25,921,785	97,788,525	4,773,138	2,505,321	23,893,899	84,920,225	8,542,494	10,843 [2]	248,446,230
1914	24,101,048	99,775,327	5,062,543	3,783,148	21,919,749	97,994,900	13,118,028	7,792 [3]	265,762,535
1915	22,860,048	86,591,535	4,269,591	4,454,000	19,041,695	123,204,317	20,578,653	14,265 [3]	281,104,104
1916	23,009,455	90,951,939	3,905,003	6,470,289	17,714,235	139,934,439	21,768,096	7,705 [3]	300,767,158
1917	24,932,205	93,877,549	3,670,293	9,199,310	15,776,860	163,506,205	24,342,379	10,300 [4]	335,315,601
1918	25,401,406	97,531,997	3,220,722	12,808,506	13,365,974	179,383,015	24,207,620	7,943	355,927,716
1919	29,232,000	101,564,000	3,444,000	13,584,000	12,439,000	196,891,000	20,568,000	—	377,719,000
1920	30,511,000	105,668,000	3,059,000	17,517,000	10,772,000	240,074,000	26,801,000	—	443,402,000

[1] Michigan and Missouri.
[2] Alaska, Michigan, Missouri and New Mexico.
[3] Alaska, Michigan and Missouri.
[4] Alaska and Michigan.

Exports.—The accompanying table gives the exports of crude petroleum and refined products for the years 1908–1920 :

Exports of Crude and Refined Petroleum

(Expressed in barrels of 35 Imp. gallons.)

Year.	Crude	Naphtha, benzine, gasoline, etc.	Illuminating	Lubricating	Residuum.	Total exports.
1908 .	3,552,143	1,044,925	26,881,064	3,518,305	1,846,467	36,842,904
1909 .	4,055,660	1,637,111	24,914,309	3,848,558	2,903,957	37,359,595
1910 .	4,288,361	2,397,507	22,386,833	3,900,771	2,800,133	35,773,605
1911 .	4,805,794	3,268,916	26,483,212	4,364,752	3,189,977	42,112,651
1912 .	4,493,125	4,428,571	24,431,862	5,152,217	6,338,969	44,844,744
1913 .	4,630,227	4,477,221	26,653,361	4,943,785	10,163,622	50,868,216
1914 .	2,969,890	4,902,680	24,058,314	4,563,034	16,750,188	53,334,106
1915 .	3,768,163	6,704,078	19,944,586	5,706,631	19,338,480	55,452,838
1916 .	4,095,903	8,473,101	20,349,721	6,200,665	22,954,519	62,082,909
1917 .	4,098,122	9,961,871	15,670,380	6,677,083	26,774,384	63,121,849
1918 .	4,900,686	13,312,509	11,093,087	6,126,561	28,596,442	64,029,285
1919 .	5,024,420	8,806,309	23,443,218	6,542,742	14,710,698	59 351,287
1920 .	8,044,907	15,265,855	20,521,237	6,782,719	20,165,712	73,780,430

SOUTH AMERICA

Argentina

Petroleum in the Argentine Republic is supposed to underlie areas extending over 8,000 sq. miles, of which 400 sq. miles give superficial evidences. Two regions may be distinguished : (*a*) in the west and north-west, along the eastern border of the Andes, covering the provinces of Salta, Jujuy, Tucuman, Mendoza and Neuquen territory ; and (*b*) on the Atlantic coast, at Comodoro Rivadavia. Indications have also been reported in the provinces of Santa Fé and Buenos Aires.

The deposits occur principally in Mesozoic formations. In the Mendoza-Neuquen district the oil occurs in shales and sandstones from Upper Jurassic to Lower Cretaceous ; in the Salta-Jujuy district in a series of red-coloured shales and sandstones known as *formación petrolífera*, of which the age is not known but is presumed to be Lower and Upper Cretaceous ; and in the Comodoro Rivadavia field in rocks of Lower or Upper Cretaceous, known as *areniscas abigarradas*

or *formación de dinosaurios.* These deposits are overlaid by marine formations of Tertiary age.

The producing area is at Comodoro Rivadavia, which is situated on the Gulf of St. George, in the province of Chubut, 700 miles from Buenos Aires and 450 miles from Bahia Blanca. The Government has reserved an area extending from the Pico Salamanca in the north, to the border of Santa Cruz territory in the south.

The oil comes from a coarse, pebbly sandstone of Upper Cretaceous age, which lies on schist and granite, and is unconformably overlaid by Eocene and later beds. The strata, which are of a clayey and sandy nature, dip at a low angle, not exceeding 12 feet to the mile, and are said to form a broad shallow syncline.

The output from this field has steadily increased, and represents practically the whole of the Argentina production, which from 1907 to 1920 has been as follows:

Year.	Metric tons	Year	Metric tons.
1907	15	1914	39,357
1908	1,639	1915	73,732
1909	2,633	1916	124,286
1910	2,965	1917	163,533
1911	1,874	1918	177,626
1912	6,715	1919	172,169
1913	18,666	1920	207,301

The oil is transported by two pipe lines from the field to a topping plant on the ocean front, and eventually to storage tanks, which are connected with loading racks on a long wharf and with a deep sea loading line. In the absence of railways, transport between Comodoro Rivadavia and Buenos Aires is by tank steamer, and it is now proposed to build a commercial port at the former place.

The crude oil ranges in specific gravity from 0·940 to 0·922, and on distillation yields the following results:

	Per cent.
Naphtha and gasoline	1·5 to 3·5
Illuminating oils	15 to 19
Lubricants, fuel and coke	77 to 85

It has very good heating properties and can be used in its

crude state either by the employment of special burners or directly in internal-combustion engines.

During the war the Argentina railway companies largely adapted their locomotives to oil fuel burning, thereby using up practically the whole of the domestic production of crude oil.

New legislation in regard to the petroleum industry has been under consideration, and is understood to declare that all petroleum deposits are State property and that the Executive may itself prospect or exploit, or may do so through provincial governments or private parties.

Bolivia

Oil indications are continuous in a belt running north-west and south-east for 100 miles as far as the Argentina boundary at Yacuiba. The zone traverses the eastern provinces of Santa Cruz, Sucre and Tarija, between parallels 62° to 64° west longitude, and 19° to 22° south latitude, the traces of oil extending from near Santa Cruz southward through Sauces to Piquirenda Plata and Kuarazuti, in the province of Tarija, and into Northern Argentina. Deposits of good quality are reported at Calacoto on the Arica and La Paz Railway, suggesting a possible continuation of the Titicaca fields of Peru.

The oil strata seem to be the Lower Cretaceous dolomites, the formation being much folded and faulted. The seepages at Kuarazuti are found in two conglomerate horizons separated by clay slates, the probable thickness of the overlying strata ranging from 160 to 600 feet.

Practically no development work of any kind has so far been carried out, the commercial exploitation of the oil being almost impossible until the railway reaches the districts in question. Two railroads are projected, one west from the Paraguay River, and a second north from the Argentina frontier.

The oil is of asphaltic base and varies in composition from specific gravity 0·975, containing 4% gasoline, to specific gravity 0·810, containing 40% gasoline.

Brazil

Reports as to the presence in Brazil of petroleum in commercial quantities are numerous, but so far little active development has been engaged in to test the accuracy of any of these reports.

Activity has chiefly been shown in the state of Rio Grande, and it is reported that, on the strength of a very favourable report from some government engineers, several drilling outfits have been erected in the municipality of São Gabriel, the average daily yield of crude oil being between two and three tons.

In the State of Bahia extensive deposits of asphalt are reported near Cururupu, to the south of Port Ilheos, but have not yet been worked to any great extent.

Government engineers have also favourably reported on the prospects of finding petroleum in the states of Pernambuco, Alagoas and São Paulo.

Chile

Petroleum is reported in the north of Chile in Tarapaca province, near Puerto Porvenir and Agua Fresca in Magellanes territory, and in Punta Arenas province, north-west of Tierra del Fuego. Reports from the latter area state that very good samples of oil have been found at Rio Amarillo.

Colombia

Oil indications in Colombia are widespread, though they are met with more especially in the Caribbean, Magdalena-Santander, Tolima (Upper Magdalena) and Pacific zones.

The Caribbean zone is divisible into three parts, of which the easiest of access is a band extending from east to west 300 miles long by 50 miles wide.

The Magdalena-Santander zone in the department so named covers an area of about 10,000 sq. miles. Development has been very largely confined to this area.

The Tolima zone extends over about 7,000 sq. miles, while the Pacific zone consists of a belt from 60 to 70 miles wide, following the coast-line and comprising an area of about 1,500 sq. miles.

Legislation governing the petroleum industry has been enacted recently (Law 120 of 1919, see *Imp. Inst. Bull.* **1**, 1920, pp. 125-7): the State, whilst safeguarding rights that have been already acquired, declares its ownership of the petroleum deposits of the country. Areas are defined in which deposits may be prospected for, or exploited, and a scale of taxes to be paid has been drawn up. Eighty concessions were applied for within three days of the passing of the "Hydrocarbons Law," and the country is being prospected by 160 foreign prospecting parties, according to the *Times Trade Supplement*, of May 15, 1920.

ECUADOR

The principal petroleum region in Ecuador is that of Santa Elena, west of Guayaquil. Definite seepages are found in many places over an area of about 600 sq. miles, and it is expected that oil will be found in commercial quantities at a depth of about 1,000 feet.

Traces of oil exist in Guayas province, and in El Oro province seepages have been observed. There are asphalt deposits on Coquimbo Hill, 13 miles north-east of Cuenca, in Azuay province. Shale deposits on the shore of Abeon Bay are so saturated with oil as to be easily discernible by their heavy black colour. Indications are reported at Atacamas, north of Guayaquil, and on the east flank of the Andes, on the south side of the Pastaza River, 130 miles east by north of Guayaquil, and 40 miles from Canelos.

The oil-bearing formation, which appears to be of Miocene age, is blue shale of unknown thickness, superficial at some points, and elsewhere covered with marine debris, very spongy and resting on impermeable sandstone.

The petroleum of Santa Elena has a specific gravity of about 0·984, and is dark green in colour. It is a heavy oil, containing about 18% of kerosene. The existence of lighter oil at greater depths is possible.

Whilst the annual yield by seepage is estimated at 3,600 ons, production in a commerical sense has not really begun. There is, however, considerable activity in prospecting, and apid development is now anticipated.

By a reform of the Mining Law which took effect in October, 1919, it was decreed that oil deposits which had not then been appropriated, became the property of the State. A production tax of from 5 to 10% of the gross production was also fixed.

Peru

The Peruvian petroleum fields may be divided into two general districts—the Andes, containing the Titicaca field, and the Pacific coast district, including the Zorritos, Lobitos and Negritos fields—all in the department of Piura. Petroleum is also found in the districts of Puno, Chimbote, Jauja, Huancavelica and Ica, in fact, it is said to occur at frequent intervals from Tumbez to Lake Titicaca. The total area of oil territory is over 5,000 sq. miles, of which 200 sq. miles are stated to have been proved

Production, the greater part of which has come from the Negritos field, has been as follows .

Year.	Metric tons	Year.	Metric tons	Year	Metric tons.
1900	45,716	1907	108,052	1914	273,972
1901	44,876	1908	144,455	1915	355,322
1902	37,866	1909	188,016	1916	490,253
1903	45,496	1910	190,015	1917	361,917
1904	49,405	1911	195,408	1918	350,000
1905	53,982	1912	250,163	1919	313,000
1906	76,613	1913	304,752	1920	360,000

In Northern Peru oil is reported in sandstones of probable Eocene age, interstratified with clay, shale, etc. The beds of the upper sandstones are grey and coarse and intercalated with red and yellow clays rich in fossils, while those of the lower oil-bearing sandstones are dark and coarse and intercalated with thick, greenish clay beds, which are non-fossiliferous and more compact than the upper argillaceous beds. Borings show that deposits may be grouped into three horizons: (1) from 45 feet to 1,000 feet in depth; (2) from 1,000 feet to

1,800 feet; and (3) from 1,800 feet to 3,000 feet. The rocks are considerably broken up, but the formation is generally monoclinal, with beds dipping eastward. Some anticlines have been located, the Zorritos fields being generally associated with a wide and elongated anticline which extends along the coast. The sea-coast in the Negritos field also corresponds closely with the eastern flanks of a wide and long anticlinal structure.

According to Deustua, the oilfields of Negritos and Lobitos lie on the eastern flanks of a long and wide anticline, having its axis almost parallel to the coast. Local irregularities are introduced by secondary folds and by dip and strike faults. Thus the structure is essentially monoclinal with the beds dipping eastwards. The oil-bearing sandstones, which are of Tertiary age, are generally lenticular in form and of varied extent.

The formation in the Titicaca and other fields of the Andean district is, in general, alternating beds of limestone, clay and sandstones, the whole zone resting on a long, well-marked anticlinal flexure extending from the north-west to the south-east.

This Andean field, which now appears to be abandoned, is in the Puno region, 300 miles from the coast and 8 miles from Lake Titicaca, and extends from Cuzco to the Bolivian boundary. Exploration was most extensive in the region of Pirin, about 3 miles north-west of Pusi. The production, which in 1908 was over 10,000 tons, is now negligible.

The coastal belt stretches southward from the Ecuadorean frontier as far as Chile. The developed fields, however, extend only from the town of Tumbez, south of the Gulf of Guayaquil, for 180 miles to and beyond Paita, being bounded on the east by a spur of the Andes Mountains. The belt is about 30 miles wide and covers part of the province of Piura.

The Zorritos field, the oldest and the most northerly one, is about 24 miles south of Tumbez, the producing territory extending along the coast for about 4 miles. Most of the wells are drilled at the water's edge. The greatest depth known to have been reached is 3,020 feet, in Peroles ravine, the majority of the wells being only between 600 feet and

2,000 feet deep. There are storage tanks and a refinery at Zorritos.

The Lobitos field, 60 miles north of Paita, has a proved area of about 25 sq. miles. In 1915, a new field was reported at Punta Restin, 12 miles north of Lobitos. Much of the crude oil from this field is shipped to Ioco in Vancouver for refining.

The most southerly and the richest of the developed coastal areas is the Negritos field, 40 miles north of Paita. It includes the Lagunitos field and has an area of about 650 sq. miles. Negritos is the centre of drilling operations, and Talara, 16 miles distant, is the shipping centre, with refineries, storage tanks and wharves. There are nine large tanks with a total capacity of about 120,000 tons. The Talara refinery has a daily capacity of about 360 tons, and crude oil is also shipped for treatment in Canada and the United States.

Peruvian oil is rich in gasoline and kerosene, and yields very good lubricants. The oil in the Zorritos and Lobitos fields is of asphalt base, with a specific gravity ranging from 0·8110 to 0·8395. That in the Negritos field is of a brown colour, has marked fluorescence and is free from water, while its specific gravity ranges from 0·815 to 0·850; it yields less kerosene than the Zorritos oil. The oil from the Titicaca field has a paraffin base and yields about 15% paraffin wax.

The greater part of the petroleum output of the country is sent to the United States and Canada, the remainder going to Chile for use in the nitrate industry.

It is understood that a new law concerning petroleum is at present in preparation, concessions in the meantime only being obtainable by special act of the legislature. The registration of claims in the northern petroleum-bearing district is at present suspended by Government decree.

VENEZUELA

As an oil-producing country, Venezuela is considered to have great possibilities, numerous indications being found in the delta of the Orinoco and in the districts of El Pilar and Cumana, as well as around Lake Maracaibo. South of El Pilar are the asphalt deposits of Guanoco, with an asphalt

lake covering 1,100 acres, the product from which is stated to be much superior to that of the Trinidad pitch lake; the production in 1912–13 was 61,000 tons. Wells have also been sunk in this field, oil in quantity being expected between the shale and the underlying Punceres limestone; operations are difficult, however, owing to the unhealthy and swampy character of the region. There also appear to be asphalt and oil deposits on the delta island of Pedernales. It is, however, around Lake Maracaibo, in the districts of Rio Pauji, San Timoteo (Mene Grande field), El Mene and Inciarde, that the most important deposits are found.

Drilling has been carried on with good results in the Mene Grande field, 16 miles east of the lake, and a refinery has been built at San Lorenzo. In the Perija field, 50 miles west of Lake Maracaibo, oil has been struck in considerable quantities, and the well shut in. Additional test wells are to be put down in this and in the Limon fields.

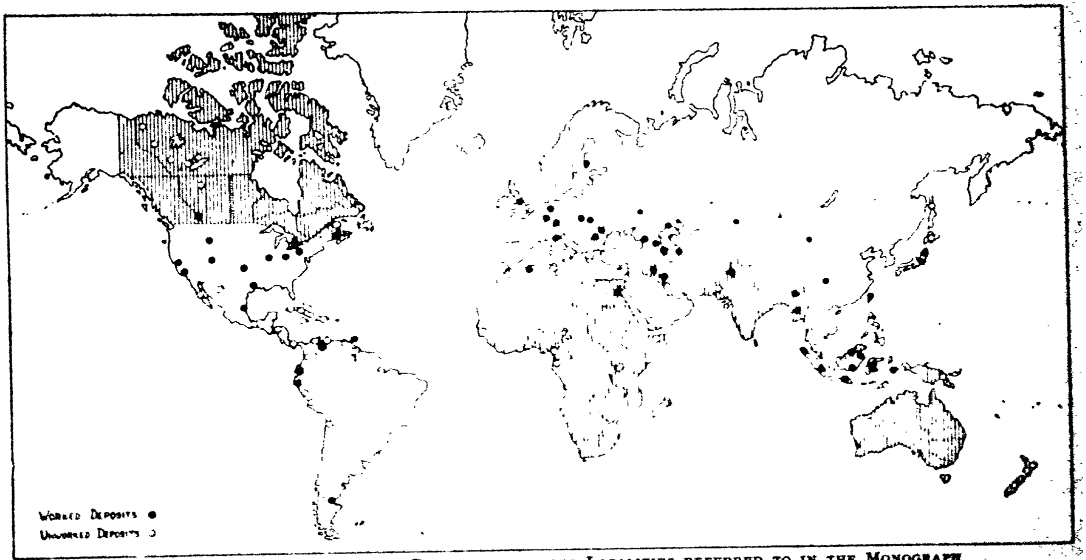
Other large concessions have been taken up on the eastern and western sides of Lake Maracaibo, and a large refinery has been built on the neighbouring island of Curaçao to deal with the production.

A concession of about 3,000 sq. miles known as Buchivacoa has been acquired in the State of Falcón, with a frontage to the Caribbean Sea.

A distillation test of typical Venezuelan oil gave the following results:

	Per cent.
Spirit below 100° C.	4·99
White oil, initial boiling-point 150° C.	0·67
Fuel oil, flash point 176° F.	74·50
Pitchy residue	15·62
Loss and refinery fuel	4·21

The productions of petroleum in Venezuela in 1917, 1918 and 1919 were 18,255, 50,710 and 64,628 metric tons respectively.



World Map showing Principal Petroleum-bearing Localities referred to in the Monograph
(British Empire shaded)

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